JANUARY 1960
In Two Sections
Section I

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ILLUMINATING ENGINEERING

Journal of the
ILLUMINATING ENGINEERING SOCIETY

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ROADWAY leading from the North Gate to the Cadet-Academic Area.

PARKING AREA on the Academy grounds.

ATHLETIC FIELDS use 60′ and 100′ steel poles.

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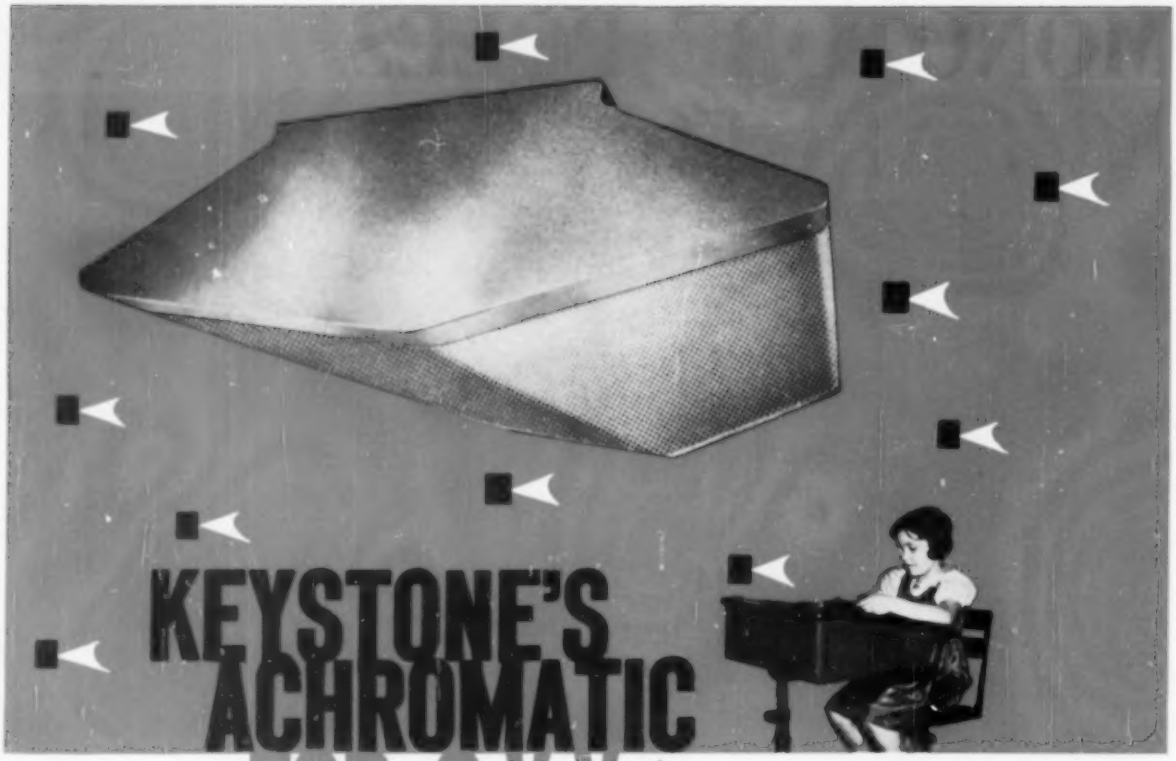
UNION METAL

The Union Metal Manufacturing Co.
Canton 5, Ohio · Brampton, Ontario

Monotube Engineered Lighting Poles



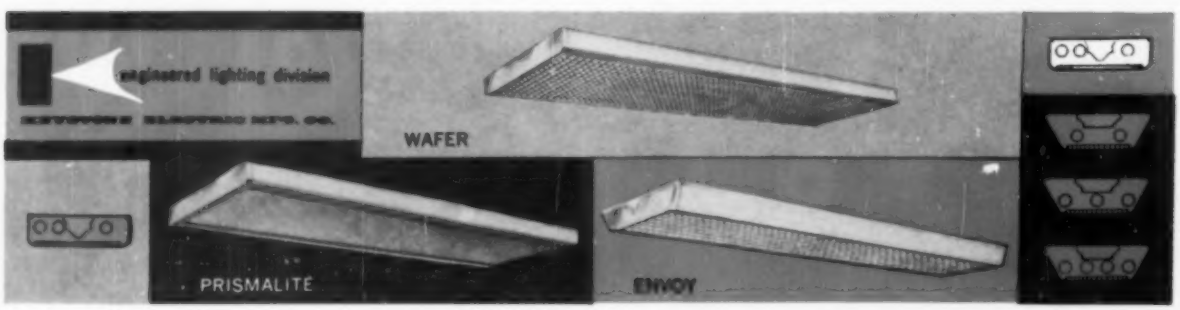
KEYSTONE'S ACHROMATIC ...FOR O.V.V.*

Keystone's Engineered Lighting Division recently announced a new series of fluorescent fixtures specially designed for schools, offices, stores, institutions and public buildings. Featured in this 4-foot and 8-foot series is the Achromatic, a 2 or 3 lamp quality luminaire which has become the industry's leader in a few short weeks.

Since 1898, footcandle levels have doubled every 10 years. Due to a more scientific evaluation of required lighting levels, the new series developed by Keystone has resulted in luminaires that provide *Optimum Visual Value and 'see-ability.' The series offers a brand new concept in controlled refraction of light. This concept provides uniformity of brightness without harsh shadow reflection. Maximum illumination is delivered at peak efficiencies. In addition to the Achromatic, other fluorescent fixtures in the new series include the Wafer, Prismalite and Envoy. Rapid start and slimline models are available for a number of versatile mounting arrangements. For additional information, send for Bulletin #F 859.

* *optimum visual value*

KEYSTONE ELECTRIC MFG. CO. / *PHILADELPHIA 34, PA. SINCE 1932*



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ILLUMINATING ENGINEERING

THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

January
1960

Vol. LV, No. 1

In Two Sections
Section 1

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Here's a Shining Example of Functional Lighting without Glare — by LITECONTROL

The illumination of a display room devoted to trays, trophies, jewelry and other gleaming items, represents some special problems. Reflection can get out of hand unless controlled. The task can be a challenge for the architect, contractor and lighting equipment manufacturer.

For the new display room of the L. G. Balfour Company, illustrated, Litecontrol's luminous lens ceiling was a happy choice. The merchandise is gently accented by light of the precise intensity required. There is no excess brightness to distract or strain the eyes. The removable lenses lift out quickly for easy servicing of the fixture.

This equipment is one of Litecontrol's most popular systems. You'll find it and other standard, cost-saving units right in your catalog for your next store, office, bank, school or other commercial installation.

INSTALLATION: L. G. Balfour Company, Attleboro, Mass.
AREA SHOWN: Showroom
ARCHITECT: Charles G. Everett, Pawtucket, R. I.
ELECTRICAL CONTRACTOR: A. C. Burt, Attleboro, Massachusetts
DISTRIBUTOR: Graybar Electric Co., Inc., Providence, R. I.
FINISHES: Ceiling — Off-White. Trophy Cases — Mahogany
CEILING: Litecontrol Luminous Lens-Ceiling, using Holophane #6024 acrylic lenses; 40 watt Rapid Start strip fixtures on 24" centers
INTENSITY: Average, 75 footcandles in service

LITECONTROL
Fixtures
KEEP UPKEEP DOWN
LITECONTROL CORPORATION.
36 Pleasant Street, Watertown 72, Massachusetts

DESIGNERS, ENGINEERS AND MANUFACTURERS OF FLUORESCENT LIGHTING EQUIPMENT DISTRIBUTED ONLY THROUGH ACCREDITED WHOLESALERS

Silvered-bowl lamps, installed on four-foot five-inch centers in 30-inch plenum over aluminum honeycomb louvers produce even brightness distribution at reasonable cost. Dark areas on ceiling are spots of color—three 75-watt red, green and blue incandescent lamps, installed in enclosed metal boxes for esthetic interest on ceiling. Separate dimmer controls for colored and silvered-bowl lamps permit many varied atmospheres. Bare 500-watt lamps seen in photo below are remains of clubroom's old lighting, five indirect fixtures.

American Legion Post No. 5

milj

NATIONAL ENTRY
Class II

It is a well-known and often proved maxim that the flexibility of an area is directly related to its lighting design. Recent reports of a multi-purpose ballroom (November IE, page 671) and hotel roof garden (December IE, page 749) attest to the fact that here is a fertile area for imaginative illuminating engineering. One more case in point is the relighting of the 3500-square foot headquarters of American Legion Post No. 5 in Pittsburgh, Pa.

Rapid growth in membership and prestige of Post No. 5 soon obsoleted the group's headquarters and remodeling was in order. Structural changes to meet various building codes involved a new concrete floor, stage relocation, new rest room and kitchen facilities. Even with $75,000 invested for these items, however, there was little apparent change in the appearance of the clubroom. Other improvements, even at additional cost, were decided upon, to make the Post the most practical, versatile and attractive American Legion headquarters in the area. An additional appropriation was voted—for replacement of the Post's lighting system of five 500-watt indirect fixtures.

For esthetic reasons, best lighting solution for the area was a

luminous ceiling to cover the mass of air diffusers, beams and tile on the old ceiling. Requirements for louver material were numerous: light in weight so it could be supported by the original structure above; easily maintained; sound absorbing; allow passage of conditioned air to space below; and, most important, low in brightness and high in light transmission. Material chosen to satisfy these conditions was an aluminum honeycomb louver of one-quarter-inch hexagonal cells, providing 45- by 45-degree shielding.

Since the clubroom is used primarily for dances, dinners, meetings and other activities requiring no critical seeing, 30 footcandles was chosen as the maximum practical design level of illumination. Fluorescent lamps, spaced to produce uniform brightness on the ceiling would have increased the lighting intensity beyond the established design level. Also, the expense involved in the special dimmers and ballasts required for such a large quantity of fluorescent equipment was beyond the budgetary limitations of the Post.

Incandescent lamps with standard dimming equipment would have provided the desired variable illumination system at reasonable cost. However, the close spacing necessary for uniformity with incandescent sources meant heat and wiring problems.

Light source finally chosen for the luminous ceiling system was 100-watt silvered-bowl lamps, installed on four-foot five-inch centers. The indirect characteristic of this source, which directs its light output to the freshly painted white ceiling above, produced the desired uniform brightness on wide spacing.

Decorative interest was added to the ceiling with the installation of a number of two-foot square enclosed metal boxes each housing 75-watt green, red and blue incandescent lamps. These boxes, installed in a random pattern, rest on the ceiling grids over the aluminum diffusers, resulting in clearly-defined areas of color in the ceiling. Separate dimming controls for the silvered-bowl lamps and each of the colored incandescent lamps permit a wide range of interesting lighting patterns, demonstrating the effectiveness of light used as a dynamic medium.

Vertical illumination for the walls under the air ducts is provided by deep recessed adjustable colored floodlamps. These are spaced and positioned to produce a decorative color wash on the walls. These floodlamps are also on separate dimmer control, carrying out the plan for complete versatility of all lighting elements.

Stage Lighting

Stage in Post No. 5's headquarters consists of a permanent platform with a 15-foot deep electrically-operated "roll out" platform concealed beneath. This permits flexible stage arrangements for the varied entertainment—concerts, lectures, speeches or variety acts.

Lighting for any stage position is possible with three rows of 150-watt red, blue and white projector lamps, in adjustable housings, installed in concealed positions. Two rows of these lamps, mounted over the luminous ceiling and shielded by a continuous row of honeycomb louver panels, tilted to a 30-degree angle, are for frontal spot lighting. Concealed behind the proscenium arch of the permanent platform, a third row of projector lamps lights the curved back wall of the stage.

Armand G. Zitelli, Duquesne Light Co., Pittsburgh, Pa., won first prize in the East Central Regional Contest for My Most Interesting Lighting Job with this installation.

1960 Conference Paper Outlines—Due by January 30

Deadline for submission of outlines for proposed papers for the 1960 National Technical Conference in Pittsburgh has been set at January 30, 1960. Outlines should be sent to:

Floyd W. Sell, Chairman, IES Papers Committee
Detroit Edison Company
2000 Second Avenue
Detroit 26, Michigan

Lighting a Church

When architect Arne J. Kontturi of Ashtabula, Ohio, was commissioned to design the Zion Lutheran Church in Ashtabula, he developed plans for a striking modern structure, the sanctuary of which is shown above. The interior lighting layout, however, posed a challenging design problem.

Traditional hanging fixtures, suitable for more conventional structures, had two disadvantages for this interior: (a) with a ceiling pitched at 53 degrees, surface reflections would fail to provide the quality of lighting desired; (b) hanging fixtures would, in the architect's opinion, divert the congregation's attention from the altar, which of course must be the primary focal point of the church. Experimentation with scale models eliminated conventional coves (hot spots, little or no reflection from the high-pitched ceiling).

John Carroll, Ashtabula electrical engineer, was called in and, working together, the two men came up with: two 56-foot-long coves of reflected lighting using a 3-foot slot in the face of the cove; a white matte background; low brightness 100-watt lamps to minimize bright spots; plastic diffusers, and egg-crate panels. Resulting illumination from this design is 12 to 15 footcandles at pew level. Controls include a specially-designed dimmher which can be operated from the pulpit or from the rear of the sanctuary, providing flexibiilty to lighting effects for different phases of the service. At the same time, it results in economical operation, dropping wattage in proportion to lighting level. This is important, as the cove lighting alone operates on a 12-kw demand.

The attention of the congregation is commanded to the altar by the dramatic effect of an imposing 36-foot brick cross, spotlighted and silhouetted against a striking white background. Conventional cove lighting in the entrance is also eye catching.

Lighting data was submitted by The Cleveland Electric Illuminating Co.

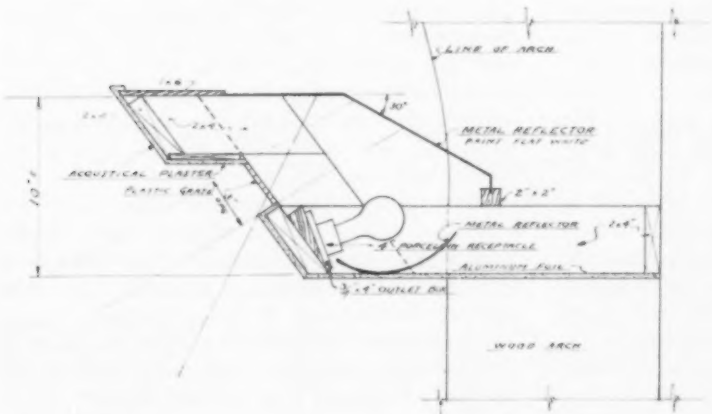

Figure 2. Cove detail of the Zion Lutheran Church in Ashtabula, Ohio. Scale: 3″ = 1′0″.

Hotel Room of Tomorrow

Spaciousness, convenience and ease of maintenance through unusual room shape, multi-purpose, built-in furnishings and extensive use of man-made materials are keynotes to interior designer Tom Lee's 1960 "Room of Tomorrow." View from terrace (above) shows uncluttered look achieved by pentagonal room shape unbroken by bathroom and closet enclosures. A cabinet between sofa-beds contains built-in telephone, remote controls for radio and television sets. Mirror behind floor lamp conceals built-in iron and ironing board. In photo at left, note one entire wall of storage cabinets containing desk, dresser, television set and, not visible, bar and wardrobe.

AVANT-GARDE in hotel-motel room design is a pentagonal-shaped guest room, designed by Tom Lee, AID, IDI, and exhibited as the "Room of Tomorrow" at the National Hotel Exposition. The softened five-sided shape of the area (slightly larger than the average hotel or motel room), with its zig-zag corridor entry, wedge-shaped bathroom and terrace, creates a feeling of spaciousness, in contrast to the cramped feeling produced by too many corners and doors and the abundance of furniture in many of today's hotel rooms.

One wall of this guest room is made of five matching laminated "walnut" storage units, housing wardrobe, dressers, desk surface, TV set, even an electric coffeemaker. Beds were designed to serve as sofas during the day and swivel out into the room at night. (Sofa's padded armrest becomes headboard for bed.) Except for cotton draperies and bedspreads, all furnishings in the room are of man-made materials for ease of maintenance.

Complementing the advanced design of the room is its lighting scheme. A multi-light wall bracket which provides general illumination over sofa-beds is the only wall decoration used by Mr. Lee. A well-placed portable supplies bed-side reading light; recessed fixtures over the edge of the storage wall direct light on this area and two decorative wall lamps are mounted inside the storage area for desk and mirror illumination.

In the bathroom, which has separate toilet and dressing areas, a recessed concave dome fixture is used for general illumination. Strip lights with G-16½ lamps mounted in perforated metal cups, painted white on the lamp-side and green on the underside, give comfortable mirror lighting for shaving and grooming.

The terrace of the "Room of Tomorrow" is a miniature lighted garden with a plastic bubble lantern and tripod planter-lamp. The tripod lamp with metal mushroom-shaped shades of blue, white and yellow adds a note of decorative charm.

For maximum flexibility of purpose and mood, in a room which must serve the many needs of the traveler, all lighting is on dimmer control.

INSTALLATION AT REEDMAN MOTORS, INC., LANGHORNE, PA.

Lighting an Automobile Showroom

LIGHTING OBJECTIVE: To provide an attractive environment and a high level of general illumination for merchandising new automobiles.

GENERAL INFORMATION: This showroom measures approximately 59 feet by 80 feet. The ceiling height is 10 feet 6 inches. Colors and reflectances of the major room surfaces are:

ceiling	white acoustical tile	70% RF
walls	walnut paneling	16% RF
floor	light gray asphalt	35% RF

INSTALLATION: Fifty-five Pittsburgh Reflecto· Co. catalog No. SS-84840 DAC surface-mounted fluorescent units (each equipped with eight 40-watt T-12 cool white rapid start lamps), forty-seven Pittsburgh catalog No. E-500-8 recessed symmetric reflector units with concentric ring louvers (each equipped with a 500-watt PS-40 incandescent lamp) and forty Pittsburgh catalog

(over)

A.I.A. File No. 31*f*

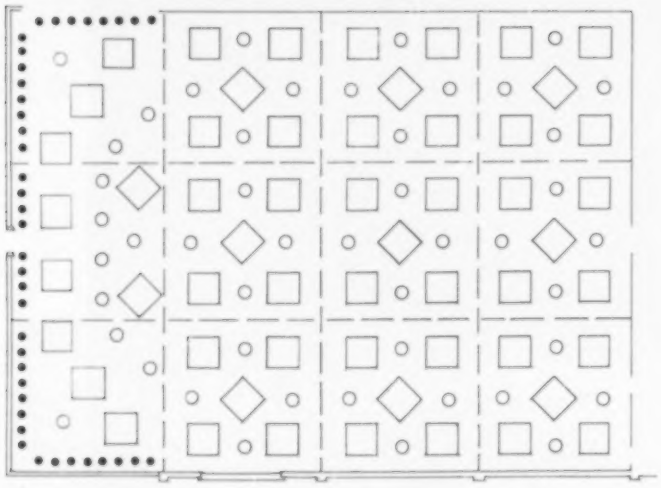

Figure 2. Plan view showing location of fluorescent units (squares), symmetric reflector units (open circles) and adjustable downlights (filled-in circles).

No. DLC-101-8 recessed adjustable downlights with concentric ring louvers (each equipped with a 200-watt PS-30 incandescent lamp), arranged as shown in Fig. 2, provide both general and supplementary lighting.

After 400 burning hours the average level of illumination in the center of the bays was 220 footcandles. Brightnesses at that time were:

luminaires		ceiling	28 fL
fluorescent at 45°	900 fL	walls	18 fL
incandescent (symmetric) at 45°	1600 fL	floors	70 fL

Lighting designed by Arthur V. Schafer, Philadelphia Electric Co., Philadelphia, Pa. Electrical contractor, Gerhart Keller, Penndel, Pa.

Lighting data submitted by Arthur V. Schafer and George T. Anderson, Jr., Philadelphia Electric Co., Philadelphia, Pa., as an illustration of good lighting practice and to aid in the design of similar installations.

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Emphasis on Esthetics

MOTIVATION research might be responsible for the new look that has become prominent in banks in recent years. The conservatism of architecture and decor, long associated with financial institutions, has been replaced by modern, sometimes daring architecture and interior design, creating a new image of the bank in the public mind.

The esthetic awakening has not been limited to architecture, however. As important as the architectural revolution is an increasing awareness of lighting as an esthetic component, as integral a part of the design as it is a functional element. Examples of design consciousness are becoming increasingly frequent—instance at hand—new building of the First National Bank of Denver.

A 28-story building in downtown Denver, largest office building in the Rocky Mountain West, is the new home of First National Bank of Denver. The building rises 437 feet from street level to the stainless steel pylon atop the tower. First four floors and basement level are occupied by the Bank; the remainder of the building is office rental space. An adjoining 6½-level, 500-car parking garage houses a four-lane, eight-teller window Auto-Bank facility. Main banking quarters consist of a two-story area—spacious central lobby and wide perimeter area, housing teller stations and officers' platform on the main floor and, on the mezzanine, other office areas.

At the main entrance to the building, a 50-foot-candle level of illumination is obtained from 200-watt annular type fixtures, with gold finished reflectors, recessed in the upper portion of the ceiling. Featured in the lower ceiling areas of the elevator lobbies, on each side of the building's main entrance, is a specially designed bronze finished luminous ceiling. This bronze ceiling, which serves as a decorative link between building lobby and bank quarters, extends through to the main banking area where, installed under the mezzanine, it is the illumination system for teller areas and the officers' platform.

Louver panels for the ceiling are composed of 1½-inch diameter aluminum cylindrical cells, having depths of one inch and 1½ inches. The panels are in 37½-inch equilateral triangular sections, supported by invisible suspension members, from each corner, forming one homogeneous luminous element. Four-foot rapid-start cool white fluorescent lamps, mounted in continuous rows on approximately 18-inch centers in the plenum, provide 120 footcandles at the teller stations and on the officers' platform. Curved acrylic plastic troughs are mounted beneath all lamps for diffusion.

In the spacious lobby area, separating teller stations and officers' platform, bronze mesh-encased columns, lighted from behind by warm white rapid-start fluorescent lamps, rise to the ceiling of the mezzanine for architectural emphasis on the height of the area. General lighting in the lobby

View of lobby and part of main banking area. Note specially designed bronze luminous ceiling installed under the mezzanine. General lighting in lobby is from 750-watt baffled downlights, recessed in high ceiling. Columns are backlighted by warm white fluorescent lamps.

On main floor officers' platform, esthetically integrated bronze luminous ceiling provides a lighting level of approximately 120 footcandles.

Trust and Estates Department, length of a city block, is lighted by recessed four-foot diameter, six-lamp fluorescent fixtures with concave acrylic plastic domes.

Looking down on suspended stairway from mezzanine. Decorative "brandy snifter" fixtures lend a soft accent of light to the modern interior.

is by 750-watt baffled downlights, recessed in the high ceiling.

To some observers, one of the most beautiful architectural elements of the First National Bank is the suspended stairway leading from the main floor to the mezzanine. Constructed from precast terrazzo treads, walnut rails and bronze hangers, the staircase is suspended from the mezzanine ceiling, giving the impression of structural independence from the building.

Complementing the design of the stairway are suspended "brandy snifter" lighting fixtures. Supplementary stair lighting is provided from mezzanine and main floor luminous ceilings.

Typical of the spacious semi-open office areas on the upper floors of the bank quarters is the Trust and Estates Department (see cut). Here, the lighting is from recessed 48-inch six-lamp rapid-start fluorescent fixtures with concave acrylic plastic diffusers, providing low brightness illumination. Functioning as an element of design, the concave acrylic plastic diffusers lend the effect of a higher ceiling area.

In a 10- by 50-foot work area outside the safe deposit vault, illumination is by a wall-to-wall luminous ceiling composed of corrugated white acrylic plastic diffusers, backlighted by 30 rows of rapid-start lamps, complete with reflectors. Illumination level produced by this lighting system is approximately 95 footcandles.

Supporting tees for the ceiling material are fabricated from acrylic plastic and are aligned with the bronze vertical mullions surrounding the area, forming an integral part of the total design.

Fred Calvert, Swanson Rink & Associates, Denver, Colo., was the lighting engineer responsible for this installation, which was entered in the Rocky Mountain Section's 1959 MMILJ contest. Raymond Narry Ervin & Associates, Denver, were architects of the building; bank interior design was by Pereira & Luckman, Los Angeles, Calif.

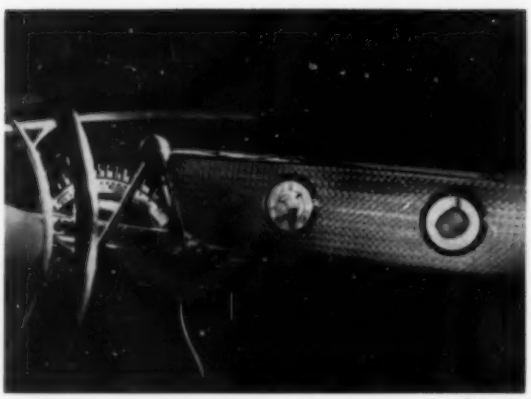
Illumination level of about 95 footcandles in work area outside safe deposit vault is obtained from wall-to-wall luminous ceiling of corrugated acrylic plastic diffusers, 30 rows of rapid-start lamps.

"Although not ready for general room illumination, electroluminescence is now by no means a laboratory novelty." So says the closing sentence of Dr. Henry F. Ivey's IES Conference paper (see page 13). A practical new light source will no doubt be developed in due time, opening up totally new possibilities for luminous interiors. Further research continues in several laboratories. Some of these are outlined by Dr. Ivey's paper, and by Dr. Strock's studies detailed on page 24). Meanwhile, the low lumen output so far available from electroluminescent lamps is already useful in numerous applications. The paper by J. M. Harris and P. J. Blinkilde (page 32) describes the application of electroluminescence to automobile instrument panel lighting. A variety of other applications are shown on these pages.

ELECTROLUMINESCENCE

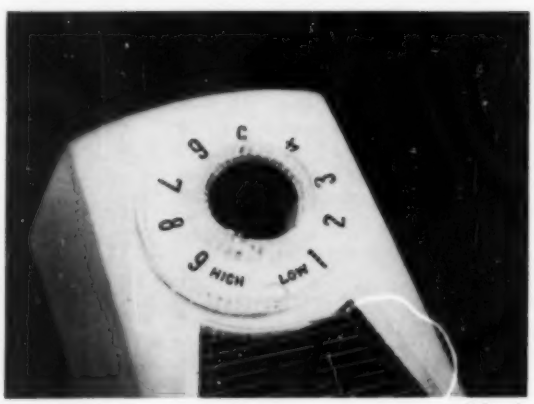
Present Status of Electroluminescence

- What is it? In electroluminescence, light is generated by phosphors excited by an alternating electric field produced by an applied voltage.
- In its simplest form a "lamp" producing light from this type of luminescence consists of crystalline phosphor powders sandwiched between two electrically conducting surfaces, at least one of which is translucent. It operates only on alernating current. Its brightness depends on the voltage and frequency of the electrical field applied across the dielectric phosphor layer.
- Potential advantages in its application lie in its simplicity (it converts electricity *directly* to light), its thin panel type of construction, its flexibility, as to size or shape, its truly uniform brightness over the entire surface, its low temperature, among others.
- Light output appears to be affected very little by the usual range of indoor and outdoor ambient temperatures. Electroluminescent lamps, are unfavorably disposed toward humidity, however.
- Useful life of electroluminescent panels has not been determined, but it seems to be at least 5000 hours. Tests indicated much longer life can be expected. Failure is gradual, rather than sudden.



Sylvania

Auto radio dial.



Sylvania

Electric blanket control.

Flip of a dial can bring changes in color and brightness to this coffee table.

Westinghouse

AT WORK

Sylvania

Luminous house numbers give sufficient light for identification from the street.

Sylvania

Decorative night light.

- Color obtained depends on the phosphors used. Lamps available so far have offered a very acceptable white, green, blue and yellow. Red is difficult, especially at lower frequencies, except with filters.

- So far, its efficiency is considerably below conventional sources—about 10 to 12 lumens-per-watt for green panels. Time may change all that. For white panels, efficiency is about half this. Actually one of its most promising aspects is an eventual efficiency which is *higher* than that of conventional sources.

- Brightness (and/or light output) so far is low, especially on 60 cycles. At present, on regular 120-volt, 60-cycle circuits, brightness is about .6 to 1.5 footlamberts in green, the brightest color; half that in white and other colors. This is, of course, useful in many applications in darkened areas. Laboratory goals are for practical light output for all lighting purposes.

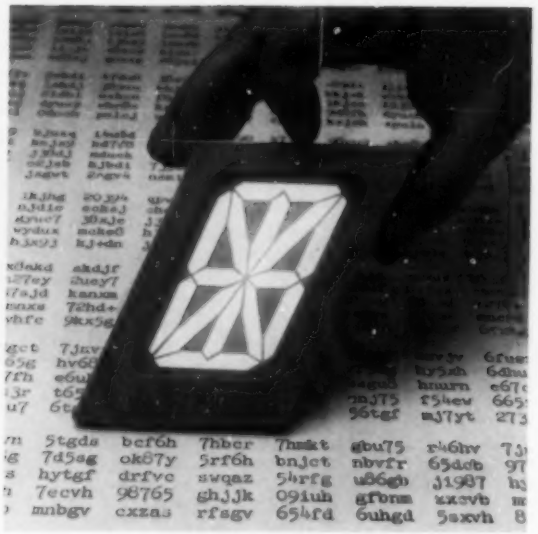
- By operating panels at higher voltage and higher frequency, greater brightness and light output can be obtained, but presently this is at still lower efficiency. Again, however, the labs are optimistic. They feel close to an answer in phosphor development and more effective materials.

- Power requirements are extremely low. For example, a 4- by 4-inch panel on 120-volt, 60-cycle source draws only 0.07 watt.

Electroluminescent Applications . . . more

Westinghouse

Display of luminous letters or numerals in various types of dials and indicators in readout equipment.



Westinghouse

This 14-segment lamp can display all letters of the alphabet, numerals 0 through 9, and symbols.

Sylvania

Indoor and outdoor thermometer.

Sylvania

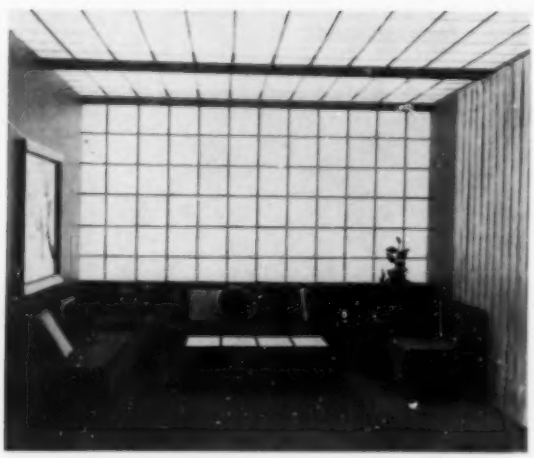
Illuminated switchplate.

Westinghouse

Plug-in night light.

Sylvania

Highway markings using electroluminescent sources are highly visible at night, as well as day.



Westinghouse

Experimental room having electroluminescent ceiling, wall, coffee table and lighted mural.

Problems and Progress In Electroluminescent Lamps

By HENRY F. IVEY

Some of the problems encountered in the design and construction of electroluminescent lamps for various applications are considered. The various types of lamp construction are reviewed. The factors affecting maintenance of output during life, the effects of the particle size of the phosphor used, the effects of the resistance of the electrodes, and an optical problem involving small illuminated areas are discussed. As more and more of these problems are solved and as more experience is gained, the different types of lamps available commercially will increase and the number of successful applications for the unique properties of electroluminescence will grow. Although not ready for general room illumination, electroluminescence is now by no means a laboratory novelty.

Electroluminescence is the generation of light in a solid material by the application of a voltage to the material, with the restriction that the light produced is not a result of heating, i.e., incandescence. Although two very different types of electroluminescence are known to exist, only the type in which a phosphor is subjected to an alternating electric field is yet of practical importance. This method of light generation was discovered by Prof. Georges Destriau in Paris in 1936,[1] and the type of electroluminescent phosphor discovered by him, zinc sulfide activated with copper and other elements, is the basis of all the electroluminescent lamps and other electroluminescent devices being made or under consideration today, although the properties of such materials have obviously been greatly improved since the time of his original discovery.

Following an extensive review of Destriau's work published in the English language[2] soon after the end of World War II, various organizations began a study of the fundamentals of electroluminescence and its possible practical applications. The first paper describing a commercial electroluminescent lamp was that of Payne, Mager, and Jerome,[3] presented before this Society in 1950. Since that time much effort has been devoted to the realization of practical electroluminescent lamps of various types and for various uses. Although such lamps are not yet developed to the stage where they may be used for purposes of general illumination, there exist many applications involving low and medium brightness levels which seem ideally suited to the properties of electroluminescence as it exists today.

It is the purpose of this paper to describe some of the present applications of electroluminescence and some of the problems in selection of materials and in lamp design which are met in the fabrication of lamps for these applications. Electroluminescence is still in a stage of infancy compared to other types of light sources and some of the difficulties encountered in its development are unique in the lamp business. It is believed, therefore, that a discussion of the experience gained in solving some of these problems will be of value. It should be understood that this is not a report of the work of a single individual but rather that of a large group; where possible, individual credit is given but this has not always been feasible.

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Effects of Phosphor Particle Size

All commercially available electroluminescent lamps make use of specially prepared phosphors in the forms of powders which are embedded in an organic (plastic) or inorganic (ceramic) dielectric and placed between two electrodes, at least one of which must obviously be transparent. It has been the general experience in fluorescent lamps and other applications of ultraviolet-excited phosphors that higher efficiency is obtained if phosphor particles are used which are as large as possible consistent with the coating requirements. Although the emission process in electroluminescent materials is essentially the same as in other types of phosphors, the effect of particle size in this case is found to be quite different, indicating a great influence of par-

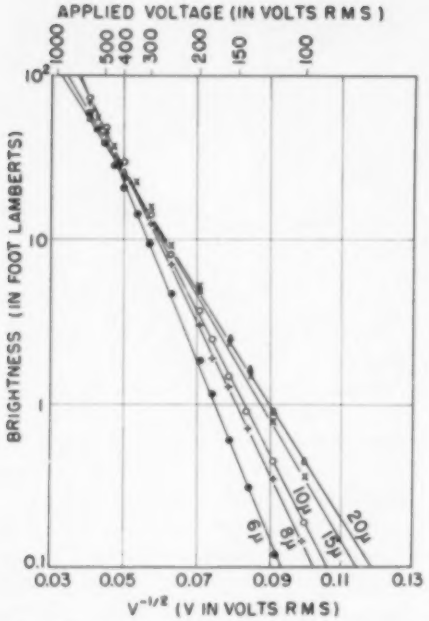

Figure 1. Effects of phosphor particle size on electroluminescence brightness as a function of applied voltage. The various fractions were separated from a single phosphor preparation (data from Lehmann).

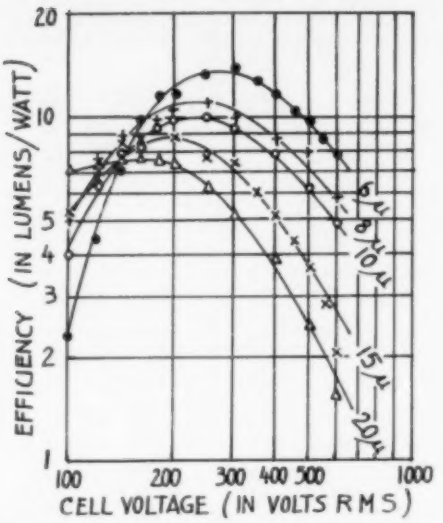

Figure 2. Effect of phosphor particle size on electroluminescence efficiency (data from Lehmann).

ticle size on the excitation process as distinguished from the emission process.

Lehmann[4] and Goldberg[5] have studied the effect of phosphor particle size on the brightness-voltage characteristic. Some typical results are shown in Fig. 1. At voltages close to the dielectric breakdown limit there is very little effect on the output, but at lower voltages the output of the smaller particles is markedly lower than that of the larger particles. On this basis alone there would seem to be little or no advantage to the use of small phosphor particles in an electroluminescent lamp. On the contrary, since the phosphor is really responsive to the electric field strength and not to the voltage alone, accidental non-uniformities in the thickness of the phosphor layer might be more easily detected in the case of small particles, and closer manufacturing tolerances would be required. It should be said, however, that for some non-illuminating applications of electroluminescence connected with solid-state image display devices, a phosphor displaying a rapid change in output with applied voltage would have a definite advantage because of the greater contrast in the image.[6]

It is when the effect of particle size on electroluminescence efficiency is considered that the benefits of the use of small phosphor particles in electroluminescent lamps are realized. This effect was first reported by Lehmann.[4] Some of his data are shown in Fig. 2, which clearly shows the improved performance of the smaller particles. In general the peak efficiency seems to vary inversely as the square root of the particle diameter. Although the particle size is of great importance, the efficiency is, of course, also influenced by other factors related to phosphor composition and preparation.

It has also been found by Thornton that the particle size of the phosphor has an important bearing on the maintenance of output during the operating life of an electroluminescent lamp, a subject which will be discussed more fully in the next section of this paper. Some experimental data for identical phosphors of various particle size embedded in a plastic dielectric are shown in Fig. 3. It is seen that the maintenance is much worse for the smaller particles. In practice, therefore, it is necessary to

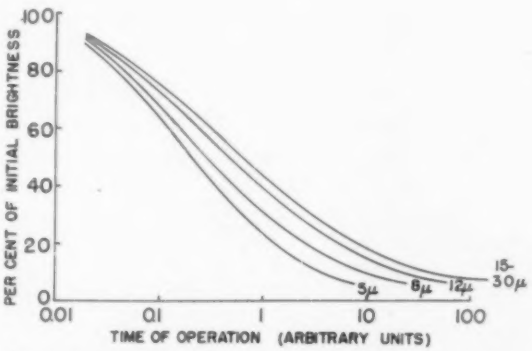

Figure 3. Effect of phosphor particle size on maintenance of output of electroluminescent lamps with plastic dielectric. The time scale will depend upon the particular phosphor used (see text). (Data from Thornton.)

effect a compromise between efficiency and maintenance in choosing the phosphor particle size to be used.

Maintenance of Output

The extent to which the output of an electroluminescent lamp declines during life is influenced by many factors, including phosphor composition and preparation conditions, particle size (as discussed above), and many others. It is also well known that the maintenance is adversely affected by the presence of water vapor; practical lamps are therefore very carefully sealed against the ingress of moisture. It now seems, as shown by Thornton,[7] that oxygen is an important factor in the loss in light output of zinc sulfide. Since the low-melting-point glasses used for embedding phosphors in ceramic type lamps are basically oxygen-containing compounds, it seems likely that reaction between the glass and the phosphor is responsible for both the lower initial output and the better maintenance generally observed in lamps of this type. The damage suffered by the phosphor when the glass frit is melted to embed it may correspond to that suffered during several hundred hours of operation in a plastic-embedded lamp. According to this picture a ceramic-embedded lamp starts life at a point corresponding to a time greater than zero on the curves of Fig. 3 and hence has a higher percentage maintenance but lower initial output.

The maintenance of output of an electroluminescent lamp is affected not only by the materials and techniques used in its construction but also by the way in which it is operated.[8,9] Some loss in output will always be observed even if moisture is scrupulously avoided. The amount of deterioration is greater the higher the operating frequency. For operation at very hight frequencies, as pointed out by Sack, the output after a certain time of operation is determined by the number of cycles of alternating voltage to which the lamp has been subjected, i.e., to the product of frequency and time. As shown in Fig. 4, at low frequencies the life is generally somewhat greater than predicted on this basis. At the time this paper was written, laboratory tests on a specially prepared yellow-emitting phosphor indicated that 10^{10} cycles of high-frequency operation were required to reduce the brightness to half the initial value. For operation at 4000 cps, 10^{10} cycles corresponds to 700 hours or about one month of continuous operation. The corresponding time for 60 cps operation should be at least 200 times this or about 20 years! Since the loss in output is more rapid during the early hours of life, the apparent maintenancet will be improved if expressed as a percentage of the output at 100 hours (the standard practice for fluorescent lamps) rather than the initial output.

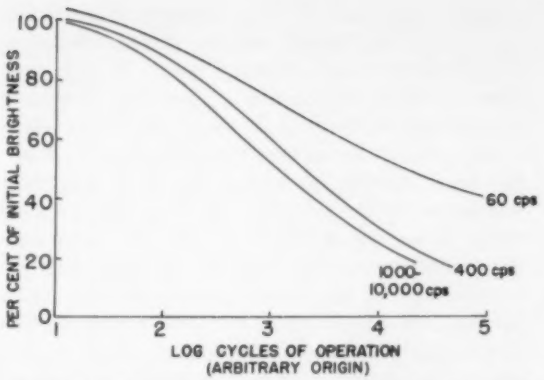

Figure 4. Effect of frequency upon maintenance of output of electroluminescencent lamps with plastic dielectric. The time scale will depond upon the particular phosphor used (data from Thornton).

If the output is measured at the same voltage as that at which the lamp is aged, and if the phosphor is uniformly distributed throughout the dielectric layer, then it is found that the maintenance of output is affected very little, if at all, by the magnitude of the applied voltage. The characteristic of output as a function of voltage, however, may be changed markedly.[7,8] The rate of deterioration of output in general increases as the temperature is increased; measurements at the temperature of liquid nitrogen have indicated essentially no decline in output.[9] It is believed that the decrease in output is the result of electrolytic migration in the solid phosphor particles;[7-9] even with very low ionic mobilities appreciable effects can result because of the very high field strengths and very long times involved.

Until recently it was found that the maintenance characteristics of blue electroluminescent phosphors were inferior to those of green emitters and that these in turn were worse than yellow phosphors. Recent developments in phosphor preparation, however, have resulted in green and blue phosphors with maintenance characteristics approximating those of the yellow phosphors. Equality of maintenance is obviously an important factor in the preparation of white-emitting phosphor blends if color shifts during life are to be avoided.

It is generally believed that electroluminescent excitation is limited to very small regions of the phosphor particles. Thornton[7] suggests that this localization is greater at high frequencies as well as at low applied voltages. This view is supported by a variety of experimental evidence. Perhaps the most striking is that "two lifetimes" may be obtained from an electroluminescent lamp in the following

manner. The lamp is first operated at high frequency and low voltage and the output allowed to deteriorate to some arbitrary point. If it is then switched to a combination of low frequency and high voltage sufficiently far from the initial conditions, it will be found that the characteristic of output as a function of voltage has been essentially unchanged by the aging. If the lamp is again aged under these new conditions, it will be found that the maintenance characteristic is essentially the same as that of an identical lamp, operated under the same conditions, which had not received the first treatment. This happens because under the second set of operating conditions the excitation extends into "fresh" regions of the phosphor particles not affected by the first aging. The first "lifetime" obtained in this way will, of course, be much shorter than the second because of the higher frequency employed so that this effect is of more scientific than practical interest.

This same effect may be utilized in another way. Suppose two identical lamps are selected and operated at the same frequency. For simplicity let us say that the lamps will produce a brightness of 50 footlamberts at 400 volts or 15 footlamberts at 250 volts and that for a certain application a minimum of 15 footlamberts is required. One lamp is operated at a constant value of 400 volts until its output has decreased to 15 footlamberts. The second lamp is started at 250 volts and the voltage continuously increased during the life to maintain an output of 15 footlamberts until the required voltage has reached 400 volts. At the end of these tests both lamps would have an output of 15 footlamberts at 400 volts. In an actual experiment (performed at 4000 cps to reduce the time required) it was found that useful life for constant brightness operation was four times that for constant voltage operation.* This again follows because "fresh" regions of the phosphor are utilized as the voltage is increased in the constant brightness case.

It is also observed that the electrical impedance of an electroluminescent lamp increases during life as the light output deteriorates.[8,9] This means that the efficiency of light production may remain constant or even increase during aging in some cases. It also affords a method for artificially improving the maintenance characteristic. If excess voltage is available, an external fixed impedance may be inserted in series with the lamp and adjusted to give the desired voltage across the lamp. As the lamp ages under these conditions, the voltage across the lamp will increase because of its changing impedance and the observed maintenance will be better than for constant voltage operation. Some experimental results obtained by Thornton when a resistor is used for the external impedance are shown in Fig. 5a. Similar data for the use of an external capacitor are shown in Fig. 5b; in this case the power dissipation in the resistor is avoided. Such a capacitor may also be incorporated internally in the lamp by providing a layer of dielectric free of phosphor between the lamp electrodes. Such a layer also offers advantages from the point of view of protection against voltage breakdown.

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Effects of Electrode Resistance

The transparent conducting electrode which must be used in an electroluminescent lamp can

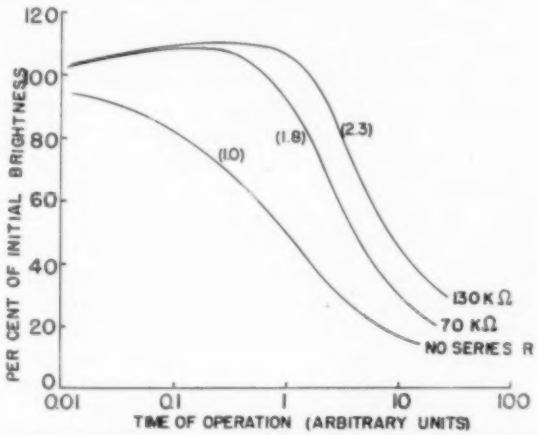

Figure 5a. Effect of external series resistor on maintenance of output of electroluminescent lamps. The voltage across the lamp initially was the same in all cases; the figures in parenthesis indicate the ratio of total applied voltage to initial lamp voltage. The time scale will depend upon the particular phosphor used (data from Thornton).

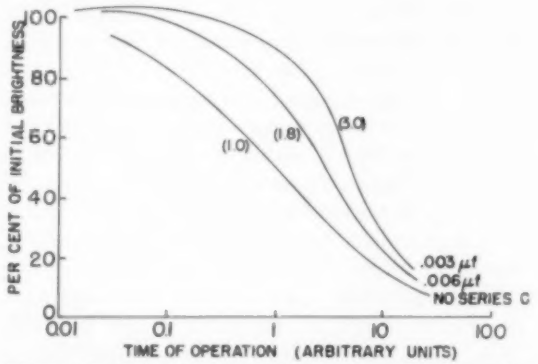

Figure 5b. Effect of external series capacitor on maintenance of output of electroluminescent lamps. The voltage across the lamp initially was the same in all cases; the figures in parentheses indicate the ratio of total applied voltage to initial lamp voltage. The time scale will depend upon the particular phosphor used (data from Thornton).

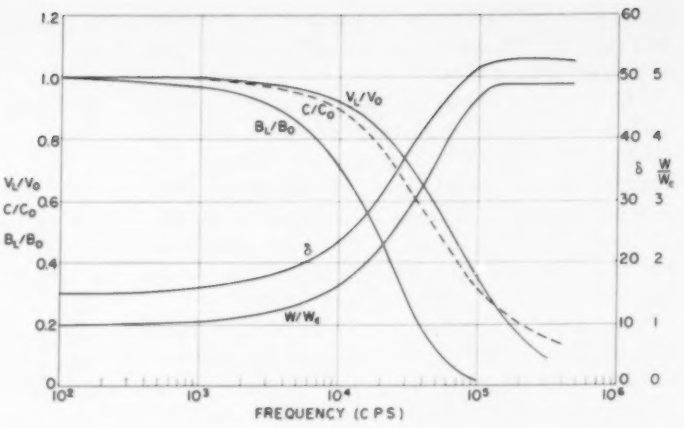

Figure 6. Effect of resistance of electrode of electroluminescent lamp on various lamp characteristics as a function of frequency as calculated on basis of simplified theory. See text for explanation of the various curves and for the lamp parameters used in the calculation.

often have an important effect on the lamp characteristics. In most cases it consists of a thin coating of tin oxide on glass. Such coatings may be made in the laboratory or obtained from various glass fabricators with optical transmission of 80 per cent or better and resistances of 50 to 100 ohms per square.* Lower resistivities are available but only at a sacrifice in transmission and therefore in light output. As the lamp current must flow through this conducting electrode, the voltage drop across it must be considered. The situation obviously becomes worse in the case of lamps of large size (the largest lamps made to date are 24 inches x 30 inches) and for operation at high frequency where the resistance becomes large compared to the essentially capacitive impedance of the phosphor-dielectric layer.

A complete theoretical analysis of the effect of resistivity of the electrode in an electroluminescent lamp is complicated by the non-linear properties of the phosphor. A simplified treatment, however, indicates that the controlling parameter is the quantity[10]

$$k = L\left(\frac{\rho\epsilon f}{2d}\right)^{\frac{1}{2}}, \qquad (1)$$

where L is the length of the cell (i.e., the length of the electrode through which the current to the most remote point of the cell must flow), ρ is the resistance (per square) of the electrode, ϵ is the dielectric constant of the phosphor-dielectric layer, d is its thickness, and f is the frequency of the applied voltage. The larger k, the greater the effects of the electrode resistance. It is seen that k is more sensitive to L than to the other factors; doubling the length of the cell has the same effect as increasing the frequency by a factor of four.

*A little thought will convince one that the resistance between two opposite edges of a square conductor is a function only of the material used and its thickness and is independent of the edge length.

The resistance of the electrode will have several effects on lamp performance. Fig. 6 shows the results of the approximate calculations (neglecting nonlinearity effects) for the following typical values: $d = 2$ mils, $L = 12$ inches, $\rho = 100$ ohms/square, $\epsilon = 5$, and $\phi = 75$ degrees (ϕ is the phase angle of the phosphor-dielectric layer). The various curves of the figure represent the frequency dependence of the following effects:

(1) There will be a voltage drop across the resistive electrode and therefore the voltage, V_L, across the phosphor-dielectric layer at the edge of the lamp at a distance L from the electrode contact will be less than the applied voltage, V_o. This is shown by the curve labeled V_L/V_o.

(2) Since the output depends strongly on the voltage there will be a variation in brightness across the lamp represented by the ratio B_L/B_o, where B_o is the brightness immediately adjacent the contact and B_L is that at the opposite side. The curve plotted is for the case $B_L/B_o = (V_L/V_o)^4$, which is true if a lamp is operated at the voltage for maximum efficiency, which is about half the normal rated voltage.[11] At rated voltage the corresponding exponent is roughly two instead of four and the resultant curve lies between those shown here for V_L/V_o and B_L/B_o.

(3) Because of losses in the resistive electrode the power consumption of the entire lamp, W, will be greater than the power W_ϵ, which is actually dissipated in the phosphor-dielectric layer and available for light production. This effect is shown by the curve labeled W/W_ϵ.

(4) The measured electrical capacitance of the lamp, C, will be less than the value, C_o, at frequencies so low that the effect of the electrode resistance is negligible, as shown by the curve C/C_o.

(5) The measured phase angle, ψ, will vary from the value characteristic of the phosphor-dielectric

layer, ϕ, to half this value, $\phi/2$, at high frequencies. In Fig. 6 the loss angle $\delta = (90 \text{ degrees} - \psi)$ is plotted rather than ϕ itself.

(6) The heat generated in the resistive coating (which will not be uniformly generated over the lamp) will also affect the phosphor output; depending on the phosphor and the frequency used, increased temperature may either lower or increase the output.[12] This effect is, therefore, difficult to calculate but will have an additional influence on the idealized B_L/B_o curve shown in Fig. 6.

The curves of Fig. 6 apply only to the specific example cited. It will be recalled from Eq. (1) that doubling the length of the cell, L, is equivalent to multiplying the frequency by four. Thus for a cell four inches long, the frequency scale in Fig. 6 should be multiplied by a factor of roughly ten; for a cell 1.2 inches long, by a factor of 100; and for a cell two feet long, by a factor of 0.25. The effects of electrode resistance may obviously be minimized by making contact to the electrode on more than one side or by overlaying it with strips or a network of lines of a material with higher conductivity,[13] provided that the latter is not objectionable from the viewpoint of appearance.

Optical Problems in Electroluminescent Information Display Lamps

Electroluminescent lamps with sub-divided electrodes for the display of numerical or alphabetical information were first described by Sack.[14] A seven-segment design is sufficient to form by suitable switching means any number from 0 through 9. Fig. 7a shows a ten-segment design with improved legibility; in addition to numbers this lamp can also display sixteen letters of the alphabet and many symbols, including positive and negative signs. The fourteen-segment design of Fig. 7b permits display of all the numerals, letters and additional symbols. In these lamps the second electrode is undivided and common to all segments. Such display lamps

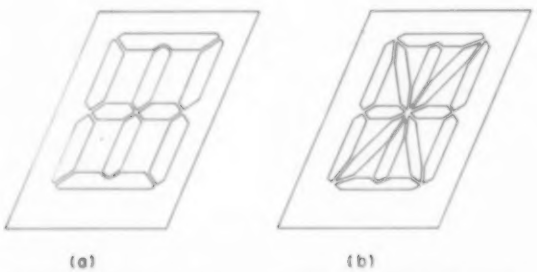

Figure 7. Electrode segment designs for typical electroluminescent information display (numerical or alphabetical) lamps. (a) is ten-segment design; (b) is fourteen-segment design.

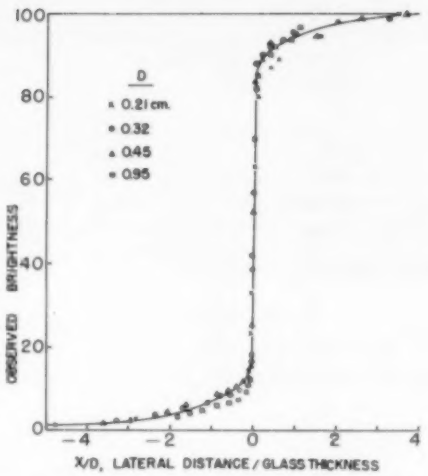

Figure 8. Measured brightness across the boundary between illuminated and unilluminated areas of electroluminescent lamps with glass bases of four different thicknesses. As abscissa is plotted the distance from the boundary divided by the thickness of the base (data from Thornton).

should find application in digital voltmeters, computer read-out devices, stock quotation boards, athletic score boards, train or airplane indicators, etc. For such uses electroluminescence has many advantages over the incandescent or glow-discharge lamps and electro-mechanical devices now used. These include a "fail-safe" feature (the light output declines slowly during life rather than ending catastrophically), long life, high reliability, small space due to thinness of the lamp, good legibility, wide-angle viewing, lack of parallax, and low power consumption (approximately 0.1 watt per letter or numeral).

In one design of lamps of this type the illuminated segments are only 5/32-inch wide. It was found that the brightness obtained was lower than than expected on the basis of measurements on lamps with larger illuminated areas. Investigation showed that the lower output was not due to any deficiency in the phosphor, but resulted solely from an optical effect resulting from the geometry. Light from the illuminated area is lost to non-illuminated areas of the lamp by inter-reflections in the glass base. If the adjacent area were itself illuminated, then the light lost in this way would be compensated for by light coming from the adjacent area.

Fig. 8 shows some measurements made by Thornton on the distribution of brightness near the boundary between an illuminated and a non-illuminated area for several thicknesses of glass base. Although most of the change in output occurs near the boundary as expected, there is a small variation

in brightness on either side. This effect can obviously be minimized by reducing the glass thickness. The index of refraction of the glass will also affect the result but it is generally not feasible to vary this.

Various Types of Electroluminescent Lamp Construction

Electroluminescent lamps may be made in a variety of ways. The phosphor may be coated over two wires which serve as electrodes and are wound on a cylindrical or other shaped form.[3] The electrodes may also consist of two sets of interlocking fingers arranged much like the teeth of a comb with both electrodes in one plane. In these cases neither electrode need actually be transparent; the light emission, however, is not uniform over the area. More generally one electrode is transparent and the other is parallel to it and spaced a short distance from it.[2] Even in this case, however, a wide variety of different constructions are possible. For practical lamps the phosphor may be embedded in a plastic dielectric and coated on a glass base. The embedded material may also consist of a low-melting-point glass or enamel[15,16]; in this case the base may be of either glass or metal.

A special type of lamp with subdivided electrodes for the display of numerical or alphabetical information has been discussed above. Pictorial or advertising displays with a prearranged pattern may obviously be fashioned in a similar way.[17] If the two electrodes of the lamp consist of two nonparallel sets of stripes which form a Cartesian coordinate system, then pictorial information of any kind may be presented.[18,19] Such devices hold great promise for flat solid-state radar or television displays of the future; some of the difficulties to be overcome before they are commercial practical have been summarized elsewhere.[20]

Multi-layer lamps with the different layers containing phosphors emitting with different colors may be made, either with plastic or glass embedment of the phosphor.[21] By varying the voltages applied to the three layers the color may be continuously varied over a wide range. Such lamps are being experimentally adapted to the illumination of aircraft instruments*; here a change in color may be used as a warning indication or to present additional information. Each layer of such a multi-layer lamp (which is essentially a capacitor) may also be tuned to a different frequency by an inductor so that the color will vary as the applied frequency is changed. Single-layer lamps may also be made

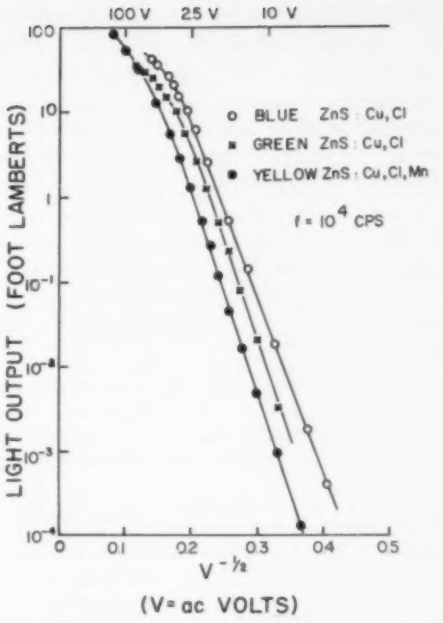

Figure 9. Electroluminescence brightness as a function of voltage for thin zinc sulfide phosphor films (data from Thornton).

with special phosphors which show a shift in emission color with applied frequency.[20]

Although not yet developed to the same state as rigid electroluminescent lamps, construction of flexible lamps is also possible.[22,23] In this case the phosphor must be embedded in a plastic dielectric. The largest single problem in construction of such lamps is, perhaps, that of a flexible transparent conducting electrode. Metal mesh or woven glass cloth[23] made conducting with tin oxide may be used. The temperature required for application of tin oxide coatings is too high to permit their formation on plastic materials. The need for good conducting films which may be applied to thin plastic sheets is perhaps the biggest obstacle in the commercial exploitation of flexible electroluminescent lamps.

All of the types of lamps discussed so far in this paper involve an electroluminescent phosphor powder embedded in some dielectric. It is also possible in the laboratory to prepare continuous transparent electroluminescent phosphor films on a glass base. Such films may be only a few microns in thickness. Some experimental results obtained by Thornton[24] are shown in Fig. 9. It is seen that appreciable light output can be obtained from such films even at the present stage of development. Because of the thinness, comparatively low voltages are required. Such films, therefore, offer advantages when lamps operating at low voltages are required or when transparency of the lamp is de-

*Such work has been supported by the Wright Air Development Center under Contract AF33(616)-5811.

sired. Thin phosphor films will also emit light when operated on direct voltage rather than on alternating voltage and this is an additional advantage; the light output for operation on d-c is, however, considerably lower than that obtainable for high-frequency a-c operation. The uniformity and reproducibility of thin phosphor films at the present time do not permit their application in commercial lamps. If electroluminescent lamps in general are in a stage of infancy, then thin film lamps must be said to be in an embryonic state. Nevertheless, they do offer very interesting opportunities for future developments.

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DISCUSSION

K. H. BUTLER:* Dr: Ivey has presented a paper which appears to be valuable for potential users of electroluminescence because of his discussion of efficiency and maintenance of light output during life. However, a careful study shows very serious deficiencies both in data presented and in data not presented.

Considering first the data presented, Fig. 1 shows the effect of voltage on brightness as a function of particle size. It is unfortunate that neither this paper nor the original paper by Lehmann indicates the frequency used or the thickness of the cell. The measurements were apparently taken with castor oil as a dielectric so that the data cannot be used directly for practical lamps.

Fig. 2 shows efficiency data. Here again the data applied to castor oil cells rather than to practical lamps and there is no data on frequency of operation.

While efficiency can be an important factor when electroluminescence is used to light large areas, such as the highway signs shown in the IES 1959 Progress Report, for most uses the surface brightness is much more vital. With lamps for operation at 120 volts, the factor determining the minimum dielectric thickness is breakdown voltage. The data presented by Dr. Ivey show clearly that large particle size phosphor will give both higher brightness and better maintenance at a given voltage and thickness. These results confirm our production tests over the last few years on lamps using ceramic dielectrics.

The use of an arbitrary time scale in Fig. 3 showing the maintenance of experimental lamps made with plastic dielectric is unfortunate, as is the use of a log scale for time. This presentation minimizes the very rapid decay early in life which is frequently found with plastic lamps. If the unit of time in Fig. 3 is 1000 hours, then the maintenance for 15-30μ phosphor in plastic lamps is only 75 per cent at 100 hours and 45 per cent at 1000 hours.

I agree with Dr. Ivey that sealing against ingress of moisture is vital for long life with good maintenance with plastic lamps. It demands extreme care in design and in manufacture of the lamp and thus places restrictions on potential applications of electroluminescence. The current trend toward ceramic dielectrics reflects the desire to avoid such restrictions on size and shape, in addition to a desire to benefit from the better maintenance.

There appears to be some error in the scale of Fig. 4 since at 1000 cps operation, 10^5 cycles would only be 100 seconds. In the text Dr. Ivey discusses 10^{10} cycles of operation as giving 50 per cent maintenance. While this may be unusually long life for 60 cps, it bears out our experience with ceramic lamps which normally show 60 per cent of initial light output at 25,000 hours on 60-cycle operation.

The effect of series impedance shown in Figs. 5a and 5b is of interest and I hope to see a more detailed publication. The use of a series resistance or capacitor has been common practice as a current or voltage limiting device to protect the lamps from high voltage transients. With vibration or transistor power supplies for automotive uses[1] voltage limitation is used while with 60-cycle lines current limitation is more usual.

Dr. Ivey refers briefly to special uses of electroluminescence. The 1959 IES Progress Report also mentioned the use in control panels for aircraft where environmental requirements are very severe. The use of display devices both for momentary display and for stored information has aroused great interest in the last few years.[2]

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The author points up the need for good conducting films on plastic sheets as a requisite for commercial exploitation of flexible lamps. Another requisite for long life and good maintenance is a thin plastic which is an adequate barrier to moisture vapor penetration. While considerable improvements in plastic have been made, at present the penetration of water vapor is still best solved with ceramic materials.

Turning to the omissions in the paper, it would have been greatly improved by a presentation of data on the possible colors obtainable either by direct excitation or by the use of photoluminescent materials excited by the electroluminescent light. Blue, green and yellow can be obtained directly[3] with good surface brightness, while even deep reds are possible with cascade excitation. White lamps can be made with either direct or casade excitation with a range of tint as wide as that of fluorescent lamps.

Dr. Ivey has also failed to include much useful data[4] on the effect of frequency on brightness, power factor and wave forms which are needed by potential users.

Despite my adverse comments, I feel that Dr. Ivey has helped considerably in drawing more attention to electroluminescence, the newest and least known, but the most rapidly growing light source available.

1. Harris, J. M. and Blinkilde, P. J.: "Electroluminescent Sources in Automotive Instrument Lighting," ILLUMINATING ENGINEERING, Vol. LV, No. 1, page 32, (January, 1960).
2. Butler, K. H. and Koury, F.: "The Sylvatron: A New Application of Electroluminescence," *Sylvania Technologist*, Vol. X, No. 4, page 98, (October, 1957).
3. Butler, K. H.: "Electroluminescence," *Science*, Vol. 129, page 544, (February, 1959).

A. E. MIDDLETON and H. C. FROELICH:* This paper represents an excellent review and summary of some of the recent work and thinking on electroluminescent light sources, in line with the scope of its title. The list of selected problems discussed will perhaps give an understanding, though little comfort, to the illuminating engineer who may have been led to believe that electroluminescence for general lighting is almost "around the corner." Laboratory tests, prognostications, and performance data extrapolated to long periods of time still seem to be far ahead of actual manufacturing accomplishments, even with lamps of the three available primary colors. This situation did not have its parallel in the development of the other conventional light sources.

It is unfortunate that the author has chosen to present his data with time expressed in terms of nondescript "arbitrary units." This representation does not permit any comparison with specific data using hours or some other definite unit of time which would mean more to most people familiar with the performance of light sources.

The only major points which we wish to make are in connection with the author's statements on particle size effects, which are based on Lehmann's data. The reader could receive the erroneous impression that:

(1) The light output of small phosphor particles per se is markedly lower than that of large ones and

(2) The efficiency of small particles per se is better than that of large ones.

Lehmann's data were obtained on cells of constant thickness. The voltage plotted is the cell voltage rather than the voltage on each individual particle. The phosphors do not constitute sharp particle size fractions, but broad and overlapping distributions with peaks as indicated in the figures. The author's conclusions, therefore, apply only to the light output and efficiency of large aggregates of particles as measured in cells of constant thickness.

The brightness of an EL phosphor particle is primarily a function of the voltage applied to it. Except at and near saturation of light output, where the size of the particle exerts an influence, it can be shown that the brightness of an EL phosphor particle is independent of the size of the particle. For a cell of given volume and thickness, which is occupied by phosphor particles and aggregates of varied sizes, the following holds:

(1) The number of particles will increase as their size decreases. If the voltage per particle is held constant, the electric field per particle and the light output will increase with a decrease in particle size.

(2) At a given cell voltage, the voltage per particle will decrease as the particle diameter decreases, although the average electric field remains constant. Consequently, the brightness of each particle will decrease, and the total light output of the cell will be markedly lowered because of the decrease in the voltage rather than the decrease in the size of the particles.

(3) Owing to a greater number of multiple absorptions and reflections of the emitted light at particle interfaces in the case of the smaller particles, the measured light output will be more attenuated for the small than for the large sizes. Therefore, the observed increase in lnB versus $V^{-\frac{1}{2}}$ slope with decreasing particle size will be greater than is actually the case. In other words, the slopes of the lines in Fig. 2, as obtained from unsophisticated measurements, show a greater spread than corrected values for B would give.

(4) The influence of the matrix around the phosphor particles on the efficiency will change as the particle size changes. Since cell voltage for the peak efficiency for different particle size fractions increases with decreasing particle size, the position in terms of cell voltage and the value of the peak efficiency will be a function of the relationship between the electrical properties of the matrix and the phosphor particles, and the concentration of the phosphor in the matrix. A change in the phosphor concentration will change the geometry of the matrix and thus its electrical properties.

(5) The peak efficiency for a suitable selected matrix, observed for the cell, is higher for smaller phosphor particles than for large ones primarily because the number of phosphor particles per unit volume is greater. This peak occurs at higher cell voltages because it requires a greater cell voltage to achieve approximately the same voltage on each of the small particles as on each of the large particles.

In summary, we believe the author's conclusions apply only to cells of constant thickness as made up with phosphors of different particle sizes, not to the phosphor particles per se.

GILMORE E. CROSBY:* Dr. Ivey has written a review covering many of the problems involved in electroluminescent lamps. He is careful to point out that electroluminescence can be used in numerous lighting applications, even though many problems exist. The author hedges somewhat by stating that only some problems will be discussed, thus implying that other problems exist, but have not been listed.

The section entitled "Maintenance of Output" is rather detailed in its presentation. However, it would have been helpful for Dr. Ivey to define in greater detail some of the phosphors he mentions only by emission color. The author recognizes the importance of phosphor composition and preparation yet scrupulously omits any discussion in the

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text. For example, it is known that a yellow emitter can be prepared from a zinc-sulfide host activated with manganese or from zinc-sulfoselenide activated with copper and bromine.

Our experience has indicated that the sulfoselenide phosphor is a brighter emitter and exhibits improved maintenance over other phosphors. The sulfoselenide phosphor has similar maintenance whether embedded in organic or glass dielectric. Such information regarding composition and results would have improved the usefulness of the paper.

The author suggests that general room illumination is the ultimate application of electroluminescence. Data from Lehmann are presented which show efficiencies approaching that of a tungsten lamp and brightnesses in the order of 20 to 100 footlamberts, but no relationship is shown between these results and the ultimate application. It would be helpful for the author to suggest the efficiencies and brightnesses required for general room illumination and the extent to which commercial electroluminescent lamps fill these requirements.

HENRY F. IVEY:* Messrs. Butler, Middleton, and Froelich have all called attention to the use of arbitrary time scales for presenting the information on maintenance of output. It is still our belief that this was not "unfortunate," but rather in the interests of simplicity. Since the maintenance characteristics of electroluminescent phosphors of different emission colors are not identical and are further influenced by ambient temperatures and humidity, and since the operation of lamps at different frequencies is of practical interest, it has been found that this is a very useful way of presenting such data; if the discussers have not used this technique in their own work, then we would suggest that they also might find it useful. The data of this paper were not meant to refer to any specific commercial lamps; it is to be presumed that such data will be found in the catalogs and other technical information available from the various manufacturers, but it would seem to be out of place in a general publication before a technical society.

In his remarks concerning the time scales for maintenance data, Dr. Butler arbitrarily assumes a time scale for Fig. 3 of 1000 hours. He also states that there is an error in the scale for Fig. 4. Apparently he has overlooked the statement that the logarithmic time scale has an arbitrary origin; any constant can be added to or subtracted from those given on the scale. This arbitrary origin (or the arbitrary units of Fig. 3) must be adjusted for each phosphor and set of operating conditions to give the experimentally determined half-life. Once this is done, the curves may be used to obtain the maintenance corresponding to other times. If the figure of 10^{10} cycles for half-life (time to 50 per cent of initial output) for high-frequency operation of the special phosphor mentioned in the text is applied to Fig. 4, then the figures for operation at 60 cps are 75 per cent at 35,000 hours and 60 per cent at 185,000 hours. For other phosphors and other conditions the figures would be somewhat lower. These figures are to be compared to the values of 100 hours for 50 per cent maintenance obtained by Dr. Butler from Fig. 3 with an arbitrary assumption of 1000 hours for the time unit and the value of 25,000 hours quoted for 60 per cent maintenance of ceramic lamps. We regret that misuse of these curves has caused confusion.

In response to Dr. Butler's comments concerning the relative merits of electroluminescent lamps of various types, it is our opinion that probably no one type of construction will be universally used. It seems to us that glass-plastic, all-plastic, metal-ceramic, and all ceramic lamps will all find their specialized fields of application, making best use in each case of their individual properties and peculiarities.

Dr. Butler lists as omissions of our paper the subjects of available colors, the effect of frequency on brightness, power factor, wave forms, etc. Such material was purposely omitted for a number of reasons. To have included additional material would have made the paper longer than allowable under the rules applying to papers for this meeting. The scope of the present paper is indicated in the opening sentence of the third paragraph. At this stage of progress in electroluminescent lamps it seems reasonable to assume some prior knowledge on the part of the audience; one cannot attempt to survey the entire field in each new paper. A number of extensive review papers already exist, including that of Dr. Butler cited by him (his reference No. 4) and earlier ones by the writer.[1,2] It was our object here to report information not included in the previous reviews.

The operating conditions for the data of Figs. 1 and 2 requested by Dr. Butler are a frequency of 500 cps applied to a castor-oil cell about 100 microns thick. The qualitative behavior shown, however, is observed for all frequencies, for all dielectrics, and for all cell thicknesses tested. The values of efficiency shown in Fig. 2 are independent of cell thickness and also vary but little with frequency. The effect of phosphor particle size on the brightness-voltage characteristic shown in Fig. 1 has also been observed in dielectrics other than castor oil (work supporteed by the M.I.T. Lincoln Laboratory) and will be reported in detail elsewhere in the near future.

Dr. Butler states that "with lamps for operation at 120 volts the factor determining the minimum dielectric thickness is breakdown voltage." With this we obviously quite agree. Indeed, we will go even further and say that this is true for lamps designed for any given operating voltage. From the viewpoint of brightness, practical lamps will always be operated at field strengths as high as possible consistent with reasonable safety factors on breakdown. We therefore cannot agree with the first part of Dr. Butler's statement that our data "show clearly that large particle size phosphor will give both higher brightness and better maintenance." According to Fig. 1 (where voltage, not field strength, is plotted) and other extensive experience in plastic-type electroluminescent lamps, the brightness at rated voltage will be only slightly affected by particle size. The contrary results quoted by Dr. Butler for lamps using ceramic dielectrics indicate to us the well-known fact that the characteristics of electroluminescent phosphors are generally adversely affected when embedded in ceramic layers due to chemical reaction with the dielectric at the high temperatures needed to fuse the embedding glass. This reaction is more serious with phosphor particles of small size and this probably explains the poor performance of small particles observed by Dr. Butler. We would like to point out that we are somewhat surprised that Dr. Butler differs with our interpretation of Fig. 1. As indicated in the paper (Reference 5), Dr. Paul Goldberg, who is associated with the same company as Dr. Butler, has obtained essentially identical results. It would seem, therefore, that Dr. Butler must differ with Dr. Goldberg as much as with us.

Messrs. Middleton and Froelich have extensively commented on our views concerning the effects of phosphor particle size and we have perhaps not clearly understood all their criticisms. It is possible that in some cases confusion has arisen between the brightness of an entire lamp (the light emitted per unit area of surface), the brightness of a single particle, and the total light output of a particle. Since microscopic examination shows that the light emitted

*Author.

by a single particle is distributed very non uniformly[3,4] through the volume of the particle, it does not seem very meaningful to speak of its brightness. One of the "erroneous impressions" attributed to our paper by these commenters is the fact that "the light output of small phosphor particles per se is markedly lower than that of the large ones." We do not recall having spoken of the output of a single particle but only of the brightness of the entire lamp or cell.

Messrs. Middleton and Froelich state that "It can be shown that the brightness of an EL phosphor particle is independent of the size of the particle." It seems to us that (aside from the question of the meaningfulness of speaking of the brightness of a single particle) the simplest microscopic observation of individual particles in an electric field will show that particles of the same size may differ by several orders of magnitude in their light output. If all the particles of conventional phosphors emitted as well as the best then the brightness of present-day lamps could be considerably increased.

The optical properties (transmission and scattering) of a powder layer will indeed by affected by particle size. For a given size distribution, powder content, and layer thickness, however, the transmission should be constant and independent of the intensity. The effect of particle size on optical properties will therefore be simply a vertical shift of the curves of Figs. 1 or 2 along the logarithmic axis with no effect on the slope as alleged by Middleton and Froelich. In any event we cannot understand the reference to the slopes of the curves in Fig. 2; no inference is drawn from the slopes of these curves, only the peak efficiency is of interest. The slopes in the case of Fig. 1, however, are of interest. In terms of useful lamp performance we do not believe these measurements to be "unsophisticated." Even if this were the case, we believe that a scientific fact or principle should be judged on its accuracy, and that if accuracy is preserved then simplicity is a virtue over sophistication. To introduce additional experimental evidence it may be said that it has been found that the slope of the curves of Fig. 1 are independent of phosphor concentration, indicating that optical effects are of no importance in this respect.

Under comment No. 4 of Middleton and Froelich it is stated that "A change in the phosphor concentration will change the geometry of the matrix and thus its electrical properties." Lehmann has found experimentally that the measured efficiency is independent of phosphor concentration when the latter is varied from 2 per cent to 20 per cent by volume in an oil cell. This seems at variance with the explanation advanced by these commentators (under No. 5) for the increase in efficiency observed for small particles as arising simply from the greater number of particles.

We will readily admit that some of our conclusions "apply only to the light output and efficiency of large aggregates of particles as measured in cells of constant thickness." This is, however, precisely the practical case of interest. Since the individual particles of electroluminescent phosphors are far from identical in characteristics, only a statistical average of a large number of particles is of meaning. The basic question from the standpoint of the user is: "For a given cell geometry and operating voltage (the latter obviously depends on the former), what is the effect on the output characteristics of variation in the average particle size of the phosphor, keeping the total amount of phosphor constant?" The value of the peak efficiency, however, is not a function of lamp thickness and therefore cannot be increased by varying the thickness.

Mr. Crosby asks about the composition of the phosphors mentioned in the paper. It is not our policy to give detailed compositions, nor do I think Mr. Crosby expected such information; however, it may be said that the blue and green phosphors are ZnS:Cu while the yellow emitter is ZnS:Cu, Mn. Our experience does not confirm Mr. Crosby's statements that the maintenance of Zn(S,Se):Cu is superior to that of ZnS: Cu,Mn. If he has data indicating better maintenance than the half-life of 10^{10} cycles mentioned in the paper, it would seem that the industry would be very interested in knowing of this.

The application of electroluminescence to room illumination is indeed the ultimate goal of many organizations. It is difficult to state the exact requirements for such exploitation on an economical basis as many other factors enter. However, speaking generally, it is felt that a brightness of 100 footlamberts for a white lamp, efficiency of 15 lumens/watt, and maintenance of 60 per cent of initial output after 2000 hours of operation would be sufficient to permit realization of this goal. All these figures may now be met individually, but unfortunately not yet simultaneously. Further research and development effort must be and will be expended; it is difficult, however, to estimate the length of time which will be necessary.

Mr. Crosby comments on the use of the word "some" in referring to the problems associated with electroluminescent lamps. Obviously, many types of problems exist, as with any other relatively new device, and these are of a varied nature, involving research, engineering, and manufacturing. However, it is believed that the most pertinent problems, and those of general interest, have been mentioned in the paper. We have not knowingly indulged in "hedging." In their discussion Mr. Middleton and Dr. Froelich have also stated that "Laboratory tests, prognostications, and performance data extrapolated to long periods of time still seem to be far ahead of actual manufacturing accomplishments." We can say only that we would be very surprised indeed if the reverse were true. There are always improvements in various stages of development which time and other factors have not yet permitted to be incorporated into the commercial product.

Finally, I should like to thank all the commentators for their lengthy discussion, which I believe has added to the paper as a whole, and for their kind remarks.

1. Destriau, G. and Ivey, H. F.: *Proceedings of the IRE*, 43, p. 1911 (1955).
2. Ivey, H. F.: "Component Parts," *Transactions of the IRE*, 4, p. 114 (1957); *Proceedings of the National Electronics Conference*, 13, p. 583 (1957).
3. Waymouth, J. F. and Bitter, F.: *Phys. Rev.*, 95, p. 941, (1954).
4. Zalm, P., Diemer, G. and Klasens, H. A.: *Philips Res. Rep.*, 9, p. 81 (1954).

Personnel Index — IES Directory

The Index to 1959, Part II of this issue, includes a personnel section, as well as the subject and author indexes. The personnel index, a roster of all IES committee members, national and local officers, is complete with business addresses, providing a valuable directory of active Society members.

PHOSPHORS

For Electroluminescent Lamps

By LESTER W. STROCK

Introduction of fluorescent lamps about twenty years ago made phosphors an increasingly useful and familiar electronic material. Now with new applications of electroluminescent lamps rapidly developing, the importance of phosphors will be further enhanced. This paper shows that electroluminescent (EL) phosphors are not simple and readily available raw materials, but complex technological products resulting from intense research efforts employing several scientific disciplines.

ZINC SULFIDE, the essential component of EL phosphors, has a long history as a luminescent material. It has been the subject of numerous investigations in the field of luminescence, going back to the systematic work on phosphors by Lenard and co-workers in the early 1900's when it was first recognized that the presence of foreign atoms in minute concentration is essential. Thus, there was born the concept of *activators* to which investigators of phosphor composition attributed the luminescence activity. With this as a guide in phosphor synthesis, many susbtances involving many kinds of activators were made with luminescent materials over the years. There is no need to elaborate here as such well-known texts as Pringsheim[1] and Leverenz[2] are available. As physicists looked more quantitatively into the problem as to how these activators contribute to the light emission process in terms of known atomic mechanisms and electronic processes, the concept of luminescent centers, traps, and centers responsible for the emission of specific color bands developed. These concepts assisted in making possible the development of phosphors with variable and desirable characteristics, such as color and intensity of emission, susceptibility of excitation by various means, rate of decay after excitation, stability, etc. ZnS containing various activators and with or without partial substitution of Zn by Cd and S by Se, permit the production of photoluminescent ZnS phosphors of all color emissions from blue to red and with fast or slow decay rates. These characteristics make this group of phosphors suitable for use in cathode ray and television receiver tubes, including color television. Along with advances in the art of phosphor manufacture by controlled addition of activators, considerable effort has been expended to elucidate the actual functioning of the activator as a light emitter in terms of basic physical processes.

Electroluminescent Phosphors

For many years, we have been developing and producing lamps and other devices involving an entirely different type of luminescence—electroluminescent lamps. These lamps utilize the above-mentioned electroluminescent phosphors which emit light not as a result of external irradiation as heretofore, but when placed in a thin electric condenser. The phosphor is embedded in a dielectric substance (*i.e.*, glass) of a few mils thickness. Light is emitted on application of an a-c field in the range 20-100 volts/mil. Butler[3] has recently reviewed some aspects of electroluminescent lamps including the general features of those employing ceramic dielectrics. The phosphor in most general use at present is ZnS with Cu and Cl as activators. It can also be excited by long wavelength ultraviolet to emit light of approximately the same color. The availability of a ZnS:Cu-Cl phosphor to be excited by ultraviolet (*i.e.*, photoluminescence) is not sufficient to make it emit light in an electric field. The property of electroluminescence is developed only by special processing. As with ordinary phosphors, substitution of S by Se shifts the EL colors toward red.

From the nature of the processing, and from the difficulty encountered in explaining quantitatively the process of light emission in terms of the ordinary luminescence energy band picture, it is fairly well established that, in addition to the crystal composition (the principal criterion of photoluminescence), the structure of the phosphor crystal plays a crucial role in the phenomena of electroluminescence. Therefore, as part of our phosphor development program, we have carried out an ex-

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 7-11, 1959, San Francisco, Calif. AUTHOR: Sylvania Lighting Products, a division of Sylvania Electric Products, Inc., Salem, Mass. Accepted by the Papers Committee as a Transaction of the IES.

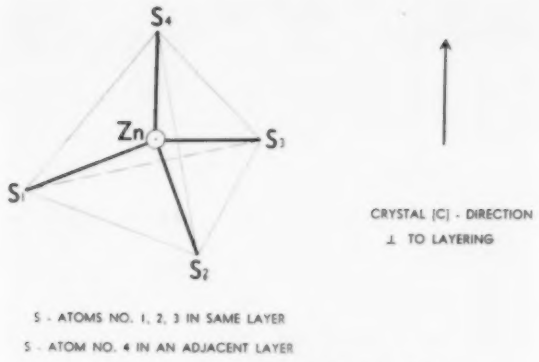

Figure 1. Tetrahedral Bonding in ZnS.

tensive research program to determine the manner in which the phosphor structure is connected with its ability to become electroluminescent and its bearing on the electroluminescent light emission process.

Structural Features of ZnS Crystals

Some aspects of the structure of ZnS crystals and particularly structural disorders, which affect certain properties of the crystal and seem to have a direct connection with electroluminescence, are presented here to illustrate the unique distinction between it and ordinary photoluminescence. To begin with, ZnS is a prominent member of the *tetrahedral* group of structures, in which each Zn atom has four S atoms as nearest neighbors located at the corners of a tetrahedron as represented in Fig. 1. Similarly, each S atom is surrounded by Zn atoms. Two different structural modifications of ZnS have been known for a long time; cubic (zincblende) and hexagonal (wurtzite), and more recently a third or rhombohedral modification has been reported by Buck and Strock.[4] All these modifications contain the basic tetrahedral arrangement of nearest neighbors.

In the cubic structure the basic tetrahedron is of regular shape, *i.e.*, equidimensional in all equivalent directions with all ZnS distances being equal. In the two other modifications, the basic tetrahedron is stretched slightly in one direction (along c axis of crystal) so that the inter-atomic distances and bond angles are no longer all equal.

The conventional description of ZnS structures in terms of their basic tetrahedra is a sufficient description of the structure for formal crystallographic purposes. However, they do not suffice for our purposes, for the reason that we are concerned with irregularities in the manner in which the tetrahedra are assembled or oriented over much larger volumes of the crystal. We want to examine the connection between gross disorders in the crystal structure and electroluminescence. It has therefore been necessary to devise a means of representing the crystal structure over many unit cells by a two dimensional representation.

Two-Dimensional Map of ZnS Crystals

The ZnS structure can be conveniently described in terms of a packing model in which rows of spheres are fitted together to form a two-dimensional hexagonal network, as shown in Fig. 2. These nets are then stacked up to form the three-dimensional crystal model. The basic geometrical features of the ZnS structure can be easily recognized from the principle of "close packing" of equal-sized spheres revealed by a model of metals, such as Cu, Ag, Mg, Zn, etc. In it, the spheres are in contact. Any four atoms of a net constitute the base (rhombic shape) of a structural unit. To achieve closest packing of identical-sized spheres, the atoms of one layer occupy hollows between three atoms of an adjacent layer. Since each structural unit of four atoms presents two hollows (located at B and C in Fig. 2), only one of which can accommodate atoms of an adjacent layer, there is a choice of two positions available with respect to the positions utilized by atoms at a distance of two layers. Depending on whether spheres of a third layer utilize hollows (of a second layer) which lie directly above spheres of the first layer (positions A), or those which lie above empty hollows (positions C) of the first layer, the resulting structure will have a two-layer or a three-layer periodicity; or in terms of a more familiar terminology, will be hexagonal or cubic. These principles are illustrated by photographs of packing models in an earlier paper[5] by the author.

The same geometrical features are present in the ZnS structure, although the density of packing is lower because of retaining the same geometry in packing two atoms of different size. In pure ZnS each layer is composed of all zinc or all sulfur atoms. For example, Zn atoms are located in half of the hollows existing on the surface of a layer of

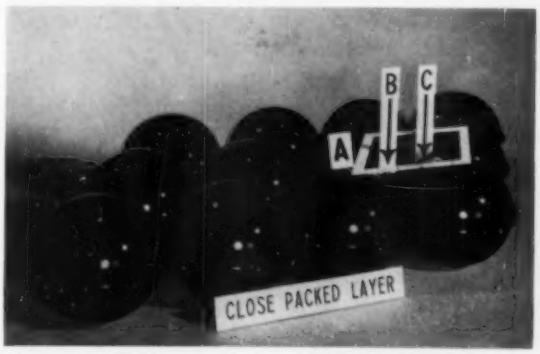

Figure 2. Hollows used in stacking additional layer.

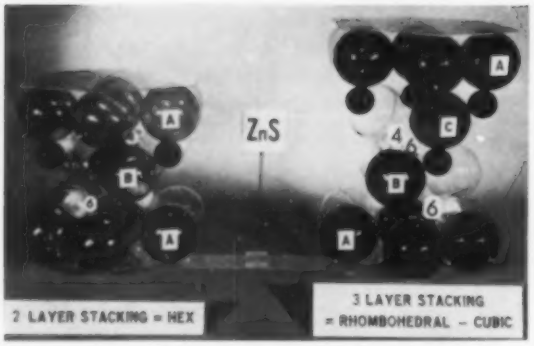

Figure 3. Structural modifications of ZnS.

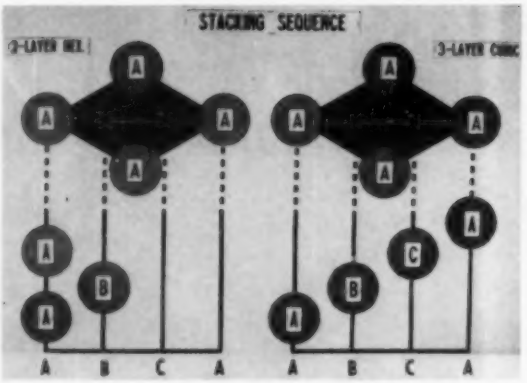

Figure 4. Stacking sequence.

S atoms which themselves are not in contact. The crystal viewed in the reversed direction along its c axis shows S atoms occupying hollows in layers of Zn atoms. In this arrangement, each Zn atom has three S-atom neighbors at equal distance in one layer and a fourth neighbor in a second S-atom layer.

The two structures, resulting from the two simplest ways of stacking alternate layers of Zn and S atoms, can be recognized in the scale models of the resulting crystallographic unit cells, illustrated in Fig. 3. In them the alignment of the nearest like neighbors of adjacent layers along a diagonal line ABC through the unit cubic cell is recognizable; whereas in the hexagonal cell the nearest like neighbors (of adjacent layers) form a zig-zag vertical line through the cell, *i.e.*, ABA — representing S atoms. Thus, the different stackings responsible for these different structures can be described in terms of a stacking sequence pattern which is easily recognizable in the structures. The concept of layer stacking thus provides an alternate manner of describing the ZnS structure and leads to a method of representing, in a two-dimensional diagram, a large number of layers in which the geometrical (and bonding) consequences of random disorders, periodic disorders (polytypes), and phase transitions are conveniently pictured. These stacking sequence diagrams are really maps of all atoms of the structure lying on the (110) structural plane, shown as a vertical projection of the unit cell base in Fig. 4, taken from an earlier paper.[5] All possible hollows for all layers of the structure lie along the three vertical lines A, B and C, any one of which is an available position for atoms on this plane. These lines are parallel with the crystal c axis, while their separation is one-third of the long diagonal of the unit cell base.

In a hexagonal structure, nearest neighbors in adjacent layers lie along zig-zag vertical lines in this diagram; in short, they have a zig-zag or 11-sequence. The two-layer periodicity in this direction is evident in the figure. It is also obvious that only two of the possible three positions are occupied by atoms in a hexagonal crystal.

In the cubic (or rhombohedral) structure, nearest neighbors lie along straight lines diagonally across the structure; the sequence is linear. The three-layer periodicity, perpendicular to the layering, is also evident in the figure.

Two-Atom Layer Displacements as Mixed Structure and Birefringence Disorders

We are now interested in possible crystal disorders as they may be represented by sequence dia-

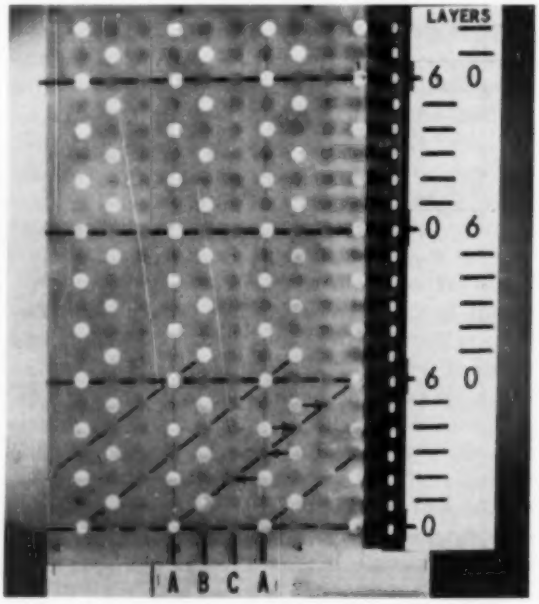

Figure 5. Hexagonal to cubic transition. Four-layer displacement in hexagonal structure.

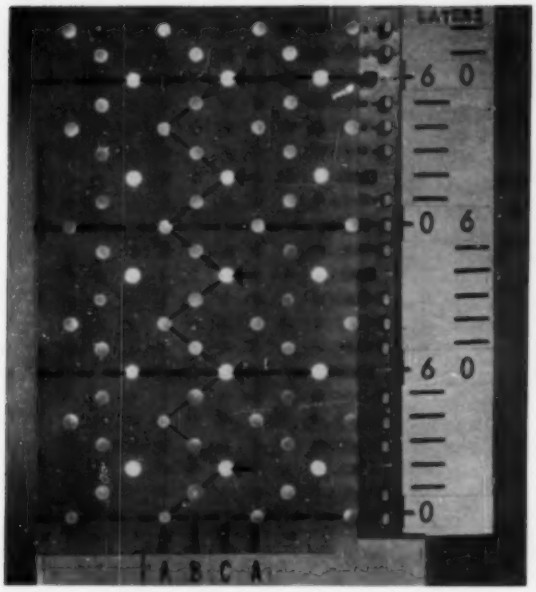

Figure 6. Four-layer polytype (22-sequence). Single-layer displacement in hexagonal structure.

grams. A hexagonal sequence diagram, extending horizontally over three and vertically over ten-unit cells, serves to illustrate partial transformation disorders. In the first place, it can be clearly demonstrated, by reference to Fig. 5, that a displacement of layers, numbers 2 and 3 to the left and of numbers 4 and 5 to the right, will convert layers 0 through 7 of the hexagonal structure from a zig-zag to a linear sequence, characterizing the cubic structure. Repeated at intervals of six layers, the entire crystal becomes cubic. Thus, a hexagonal-to-cubic phase transition is accomplished by a displacement of four layers of each six to new positions.

Now it is possible to produce displacements in ZnS crystal to a lesser extent than those which lead to a complete phase transition, both in respect to number of layers affected and the regularity of their occurrence—both during crystal growth and by subsequent treatment. As an example the displacement, as above described, in layer 2 may remain as an isolated displacement or isolated "stacking fault" occurring once, or at irregular intervals throughout the crystal. This single layer displacement of two atoms generates locally sheets of four-layer structure (sequence 22—). However, if present at regular intervals of four layers, the entire crystal becomes a homogenous four-layer polytype structure, in which each fourth layer of the parent layers are displaced, as illustrated in Fig. 6.

Another intermediate transition structure results when layers 2, 3, 4 are displaced to the left. Such three-layer displacements lead to the development of isolated sheets (unit cell thick) of reversed cubic structure in the parent hexagonal structure. The entire crystal is converted to a homogenous six-layer polytype structure when they occur at intervals of six layers, as represented in Fig. 7. Higher period polytypes develop when any of the three types of displacements (four-, three-, or one-layer) occur at greater intervals than are required to produce the homogenous transition structure (cubic, six-layer, or four-layer polytypes).

All these new structures, resulting from the displacements described, have one crucial feature in common. They have destroyed the continuity of the crystal as represented by the unbroken initial zig-zag arrangement of nearest neighbors which extended throughout the entire parent hexagonal crystal. Intermixing of structures which breaks up the structural continuity has drastic consequences on the interaction of such crystals to polarized light and x-rays, as first strikingly observed for three-layer ZnS.[6]

X-ray diffraction studies, supplemented by studies of interference phenomena in polarized light, permit a determination of the type of displacements which have operated on a parent hexagonal crystal in its attempt to transform to its stable cubic phase under the conditions existing in the EL-Phosphor activation process.

Aside from their usefulness, the optical interference phenomena are visually very fascinating. The distinct structural features of individual crys-

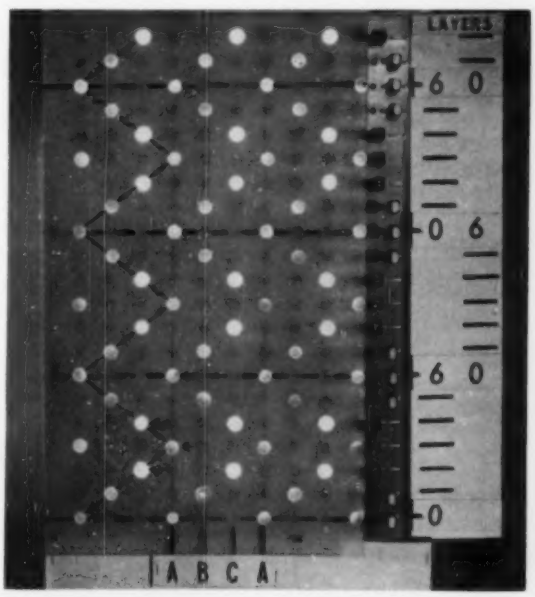

Figure 7. Six-layer polytype (33-sequence). Triple-layer displacement in hexagonal structure.

tals show up in polarized light in the form of vividly colored bands because of birefringence which can be evaluated quantitatively and photographed as permanent data. Bands of cubic structure intermixed with other structures stand out clearly as black bands in a bright colored background when crystals of mixed structure are viewed in polarized light. Crystals were found which are composed of only hexagonal structure subdivided into extremely thin sheets perpendicular to their c-axis. Optical interference color studies showed additional subdivision of the crystal on a larger scale into macroscopically resolvable plates having birefringence of many intermediate values between pure hexagonal and cubic. In this case, x-rays reveal the basic structure within these separate optically different plates. The optical studies give information on the number of layers displaced from their original hexagonal positions on the average for each plate which consists of several 10,000 atomic layers. The displacements in this case result from the utilization of a different pair of the three available positions in a hexagonal crystal.

Birefringence banding can be introduced into hexagonal crystals, grown without stacking mistakes, by subsequent thermal treatment at temperatures well below their growth temperature. The birefringence of the separate bands is a measure of the number of layers displaced from their initial hexagonal positions. The changes in some crystals have been followed up to forty hours at 800C which had converted the original hexagonal crystal to one in which no hexagonal structure was detectable by x-rays but which contained only thin sheets of reversed cubic structure intermixed on a submicroscopic scale. The reversibility of this transformation has been followed for 240 hours at 1100C.

We see, therefore, that the behavior of a ZnS crystal toward polarized light and x-rays has been greatly affected by introduction of disorders in its structure, which in turn we used as tools to study quantitatively these disorders. An interim summary of this work has been reported by Strock, Brophy, and Peters.[7]

One-Atom Layer Displacements as Birefringence Banding and Electroluminescence Disorders

The disorders, so far considered, have resulted from the simultaneous displacement of a ZnS atom pair, *i.e.*, being moved as a unit without disruption of the vertical bond between them — *a two-atom displacement*. One-atom displacements are also possible when, during crystal growth, mistakes are made by zinc atoms in attaching to underlying sulfur layers on the growth plane of the crystal. In this case, zinc atoms merely attach to three sulfurs (hollows on sulfur layer) of the existing S layer,

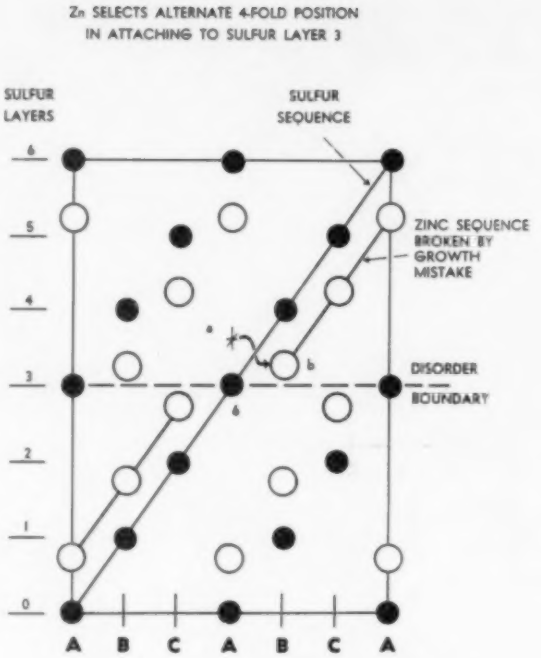

Figure 8. Growth mistake in cubic ZnS.

rather than to one sulfur, and further growth of the crystal then continues in the initial manner but with the order of Zn atoms and S atoms reversed. This represents no radical change in the structure. Zn atoms merely utilize an alternate set of available tetrahedral positions in the structure. The situation is evident from the three-layer stacking diagram of Fig. 8, which shows the change in relative positions of the Zn and S atoms resulting from the growth mistake. The boundary layer is unique in that it constitutes a layer of S atoms having six zinc neighbors, rather than the normal four. At this boundary, therefore, the tetrahedral bonding scheme of the crystal is interrupted, dividing the crystal optically into distinct portions. Thus, we have here a second type of disorder to which may be attributed the optical barriers in the crystal. This results in birefringence banding, as reported two years ago by Strock.[6]

A closely related type of *one-atom displacement* can be introduced into a completed hexagonal crystal, as illustrated in Fig. 9. The result here is quite different in that the atom displaced (sulfur) enters a lattice six-hold position (of the Zn lattice) rather than a four-fold one which led to birefringence boundaries. But as in that case, the "deserted" partner of the pair (Zn) is now surrounded by six S atoms instead of the normal four. This disorder can be introduced into a completed hexagonal crystal in isolated layers under conditions existing

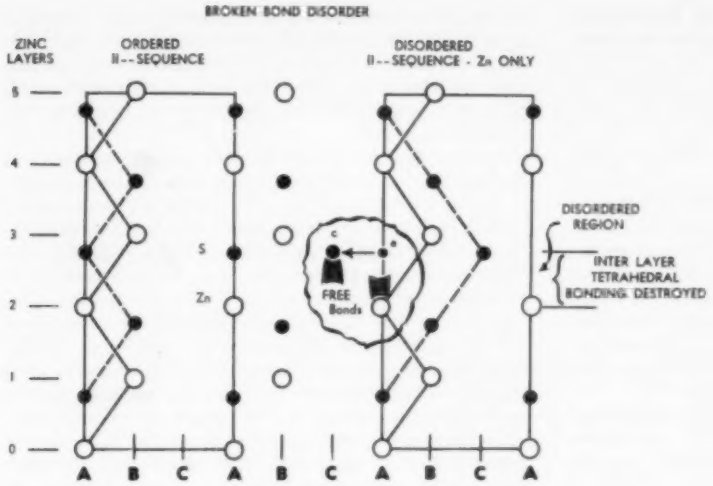

Figure 9. Single-atom layer displacement in hexagonal ZnS.

during activation of electroluminescent phosphors.

A unique feature of this third type of disorder is that a free vertical bond on two atoms is created by the displacement. After the displacement both atoms affected are not in position to enter into normal bonding relations with their neighboring atoms. This third disorder has served as a structural model in guiding our electroluminescent phosphor research.

Summary

In our efforts to determine the contribution of structural disorders to electroluminescence, it developed that EL activity frequently accompanied the development of mixed structures and optical birefringence banding in ZnS crystals, but not always. However, some crystals occasionally showed bright EL activity but no birefringence banding. This led us to the conclusion that any crystal disorder responsible for introducing EL activity into a crystal is closely related to and usually created simultaneously and under the same conditions which create the disorders specifically responsible for birefringence banding and the observed complexities in structure revealed by x-rays. The close relationship of the three possible types of "stacking disorders" in a ZnS crystal, as discussed above, support this conclusion. The disorder which converts a ZnS pair to two separated atoms with incomplete bonding in the crystal is of special significance for the phenomena of electroluminescence in that they may react with other atoms present interstitially in the ZnS crystal.

It has been the major intent of this paper to point out the essential difference between ordinary photoluminescent and electroluminescent phosphors and, particularly, the subtle and complicated role of crystal structure on electroluminescence. It is a very unique, as well as a new, luminescent material in this respect. A definite conclusion regarding a connection between crystal disorders and electroluminescence was possible only after extensive correlation with studies aimed at understanding the role of related disorders on other properties of the crystal which lead to their unique and characteristic interaction with x-rays and polarized light.

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DISCUSSION

H. C. Froelich and A. Addamiano:* It is a pleasure to read a difficult subject presented in such clear and simple language. To the uninitiated, this apparent simplicity conceals most of the physical difficulties and complexities which the author has had to overcome in unraveling some of the intricate details of the zinc sulfide structure as deduced from optical properties. This becomes apparent to those who have followed Dr. Strock's original work on the subject, which was presented at several previous occasions and of which the present paper is merely a review.

For the benefit of the audience to whom this paper is addressed, however, it should be pointed out that the subject promised by the title and the one actually treated in the article are not quite the same. The presentation deals mainly

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with the known modifications of relatively large single crystals of zinc sulfide. No practical electroluminescent lamp is presently made with such single crystals. The phosphors used in electroluminescent lamps are powders prepared by methods, and thus embodying features quite different from those found in vapor-phase or hydrothermally grown crystals which served as the basis for the author's work. It is only in the "Summary" that the author gives a hint as to how the information gained on single crystals might possibly be applied to a future understanding and improvement of electroluminescent zinc sulfide powders. Assuming that the individual crystallites in powders also contain stacking faults, one still does not know how these lattice imperfections should be deliberately introduced and controlled, what their optimum distribution and concentration should be, how they interact with activators and coactivators as well as with normal lattice faults such as vacancies, etc.

This article serves well to call attention to the type of fundamental research that must be done in conjunction with the empirical development of powders in order to possibly improve the latter.

R. E. SHRADER:* Having worked with electroluminescent materials for some time, I was glad to offer to act as reviewer of Dr. Strock's paper when the title was mentioned. On receipt of the preprint, however, I was somewhat disappointed. If the portion of the introductory section entitled, "Electroluminescent Phosphors" were to be removed, together with any mention of electroluminescence in the summary, one could retitle this paper, for example, as "Unusual Crystallographic Nature of ZnS." It could then stand complete as another excellent example of Dr. Strock's remarkable grasp of the difficult field of crystallography. However, the hypothetical relationship between electroluminescence and the disorder phenomena of the type here discussed is developed in a very weak and diffident manner and then quickly forgotten. In his haste to get at the "meat" of the paper, Dr. Strock claims that, "it is fairly well established that . . . the structure of the phosphor crystal plays a crucial role in the phenomena of electroluminescence." Dr. Strock carefully gives references from his own papers, for many of his later statements, but this vitally important one is not documented in any manner. Also at this stage he should have distinguished between single crystal electroluminescence and powder-layer electroluminescence. Even if one grants the premise for the first form it does not necessarily follow for the second, which the title implies we are dealing with in this paper.

I do not wish it to be understood that I find fault with all the statements of Dr. Strock. I agree whole-heartedly with his statement that electroluminescent phosphors require preparative processes much more specialized than those needed for photoluminescent phosphors. I will even agree that "structure plays a crucial role," but the structure I have in mind is *not* the structure of a crystallographic character as observed in vapor-grown platelets of crystals or needles of ZnS. A "chemical" structure of the microcrystals of an electroluminescent phosphor arising from the special process required has been postulated by many, in addition to myself and my colleague, Dr. S. Larach.[1] In one form or another, this has been suggested by Froelich, Ivey, Zahm, etc.[2-6] Dr. Ivey, in a bibliography in *IRE Transactions*, Vol. ED-6, p. 203, lists two hundred and ninety papers dealing with electroluminescence in ZnS. I am surprised that Dr. Strock fails to quote even one, other than his own, to indicate how well-established the role of structure is. Actually, the list does contain an article entitled, "The Effect of Disorder on the Electroluminescence of Zinc Sulphide Phosphors," by McKeag and Steward[7] which presents experimental work supporting the thesis of Dr. Strock.

However, Dr. Strock (and also, in a way, Dr. McKeag and Dr. Steward) seem to have indulged in a faulty syllogism:

(A) ZnS exhibits polytypism and disorder-phenomena in large crystals (> 25 microns).

(B) Only ZnS makes an efficient electroluminescent powder (> 15 microns) for operation in a-c fields.

Conclusion: Disorder phenomena (or its cause) is responsible for (or at least connected with) electroluminescence.

I am sure that they have not been alone in giving this conclusion considerable thought, but whereas many have decided that coincidence may well be involved between premise A, and premise B, Drs. Strock and McKeag have apparently decided against coincidence. Dr. McKeag prepared a series of powders in which he observed a relationship between maximum electroluminescence and a condition best disposed to induce disorder into a ZnS cubic structure. Although far from being a definitive experiment, it *was* an experiment. One must wonder what keeps Dr. Strock's faith so strong.

There may, conceivably, be a mysterious condition "x" which leads to polytypism or disorder in ZnS and which is, in addition, a necessary condition for electroluminescent efficiency. On the other hand, the actual coexistence of extensive *crystallographic* disorder does not seem to be necessary for electroluminescence. The evidence for this is the excellent efficiency of a blue-emitting ZnS powder Cu-activated, coactivated with iodine, which is made in one firing (30 minutes) at 700C from precipitated (cubic) ZnS. This material even with 1100C firing exhibits very little hexagonal phase, so that with 700C firing the amount or extent of a hexagonal phase or transition-induced disorder seems remote. In addition, ZnSe, for which I know of no evidence of polytypism in powders, is a remarkably good EL host material.

Even if one were to concede that crystallographic disorder or even a predisposition to disorder (in addition to "chemical" disorder due to the presence of activators) were necessary for efficient EL there is still not offered any concept as to the mechanism whereby this enables the powder to absorb energy from the a-c field and transport it to luminescent centers. It is possible that Dr. Strock's unusual and clever concept of the one-atom displacement leading to "free bonds" (Fig. 9) might form a basis for the explanation of EL. However he not only fails to develop the explanation, but also omits any evidence that this type of displacement exists.

In summary, I feel that Dr. Strock has failed completely to develop and discuss the relationship between structure and phosphors for electroluminescent lamps.

*RCA Laboratories, Princeton, N. J.

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H. F. IVEY:* Dr. Strock's excellent work on the crystallography of zinc sulfide is well-known and is a valuable addition to our understanding in this field. I am sure that everyone who has worked on electroluminescent phosphors will agree with him that they "are not simple and readily available raw materials, but complex technological products." Dr. Strock's attempts to elucidate this complex problem from the crystallographic viewpoint are therefore certainly to be welcomed.

Unfortunately, however, we have found it somewhat difficult from this paper to find what progress has really been made. It is admitted that "EL activity frequently accompanied the development of mixed structure and optical birefringence banding in ZnS crystals, but not always. However, some crystals occasionally showed bright EL activity but no birefringence banding." The situation hence seems to be far from clear-cut or conclusive. It is also stated that "A definite conclusion regarding the connection between crystal disorders and electroluminescence was possible only after extensive correlation. . . ." In view of the above statements it is not clear to us what this definite conclusion is. Perhaps Dr. Strock could discuss this point further.

Dr. Strock's crystallographic work has naturally been confined to single crystals of ZnS. We would be very interested in knowing the relationship between these results and those on the phosphor powders normally used in electroluminescent lamps, which are the subject of the paper but about which little has been said. The methods used for preparing such powders are considerably different from those for growing sizeable single crystals and hence the connection is not immediately obvious. We would also like to ask if it has yet been possible to produce in the simpler single crystals electroluminescence brightness and efficiency approaching that of the more complex commercial powders.

Finally, we would like to refer to the previous work of McKeag[1] and his colleagues on the effect of crystal disorders on electroluminescence.

1. *Journal of the Electrochemical Society*, Vol. 104, p. 41 (1957); *Nature*, Vol. 177, p. 240 (1956).

LESTER W. STROCK:** My paper attempted to summarize the pertinent results of several years' work on the structural disorders which occur in zinc sulfide and to state my conclusions as to their role in electroluminescence. Those disorders which lead to polytype structures, mixed structures, sequence reversals, and optical birefringence have been described at technical meetings and published in abstract form over the past several years.

The "broken bond disorder" (Fig. 9) was presented at the meeting covered by the abstract of reference (7) and was described in the oral presentation as a possible "El-disorder." Since then, a very active research program has been conducted using this type of disorder as a guide in El-activation experiments and as a model for describing the light emission process. The experimental results all strongly support the "broken bond disorder" as being specifically responsible for electroluminescence.

Since the strongest experimental evidence for the existence of this disorder is of a chemical nature, is based on parameters and phosphor properties, this work will be reported in detail elsewhere.

The emphasis of the present paper has been to review the evidence that a number of structural disorders occur in ZnS crystals which are spectacularly revealed by X-ray diffraction and optical birefringence phenomena, but that *these disorders do not contribute to the basic phenomenon of electroluminescence*—Dr. Shraders' philosophical and erroneous conclusion of my thinking notwithstanding. These disorders which may be grouped together as position and polarity-stacking disorders were carefully reviewed in order to clearly mark their basic difference from the one-atom displacement or "broken bond disorder" which I have deduced as being specifically and basically connected with electroluminescence. I have stated that this specific El-disorder frequently, but not always, occurs along with the described stacking disorders in ZnS single crystals.

It should not be necessary to point out explicitly to persons familiar with crystal structure or chemical structure problems, that the zinc atom—after the one-atom displacement—finds itself in a geometrical environment where a near duality of chemical bonding can exist, depending only on the manner in which and under what conditions it shares electrons with its neighboring sulfur atoms. The two bonding possibilities are approximate octahedral and tetrahedral (incomplete). A mechanism of El-emission has been developed utilizing these features of the disorder and will be described elsewhere. It was anticipated that participants in this Light Source Symposium would not be interested in these technical details.

All three discussers raised the question as to what extent crystallographic data from large-sized crystals (0.05-10mm) grown from the vapor phase can be transferred to the smaller crystals (under 0.05mm) of El-powders. In reply, I can state that individual crystals of 20- to 50-micron size isolated from electroluminescent powders show stacking faults, mixed X-ray structure, sequence reversals, and banded birefringence to the same extent and on the same scale as found and described for the larger crystals. They also show that the *same lack of 1:1 correspondence* between these structure sensitive properties and electroluminescence exists as for large crystals. Thus there can be no objection to my extension of phenomena observed so extensively on large crystals to El-powders. The situation with El-powders is, however, more complicated with respect to details.

My omission of references to others who have suggested a connection (mostly of a very general nature) between structure and electroluminescence, was deliberate. I did not include the experimental data which supports my proposed specific El-disorder, preferring to discuss relevant literature later, on publication of the experimental paper.

A Chance for Cheers

An opportunity to boast—and not only to local listeners—about a good lighting job and at the same time to publicize your Section or Chapter is offered via the Data Sheet submission contest. For listing of Data Sheet Reporters and details of the competition, which entails a small investment in time and effort but promises many beneficial returns, see page 14A.

*Westinghouse Electric Corp., Bloomfield, N. J.
**Author.

Electroluminescent Sources in Automotive Instrument Lighting

Good instrument panel lighting is a must on modern automobiles. Electroluminescence is a newly practical tool for use in the development of improved panel lighting in a precise, scientific manner.

By J. M. HARRIS and P. J. BLINKILDE

Requirements of good panel lighting could be listed as follows:

(a) Good instrument panel lighting illuminates the letters, graduations and pointers equally and with sufficient brightness to transmit the message rapidly when the driver's eyes drop to read the instruments.

(b) For maximum legibility, the hands, pointers, letters and numbers should be lighted so that they contrast with the background.

(c) Extraneous light should be minimized.

(d) Although considerable brightness is required, it should be achieved without glare.

(e) All components on an instrument panel, such as speedometer, clock and radio, should be compatible. The lighting should look alike and when dimmed, all components should dim together.

The availability of electroluminescence brought promise that additional progress could be made toward satisfying these diverse requirements. We believe the promise is fulfilled by results obtained through the application of electroluminescence on some 1960 automobile instrument panels.

History of Panel Lighting

There have been three basic approaches to instrument panel lighting: floodlighting, edgelighting, and blacklighting. In floodlighting, the light from incandescent bulbs is reflected from the side walls of the housing (and sometimes reflectors) onto the pointers and back dials (see Fig. 1). The back dials are decorated with colored numerals and graduations which become visible when light impinges on them. (Automotive engineers describe the letters, numbers, and graduation marks as "decorations.")

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 7-11, 1959, San Francisco, Calif. AUTHORS: Sylvania Lighting Products, a division of Sylvania Electric Products, Inc., Salem, Mass. and Chrysler Corp., Detroit, Mich.

Unlike floodlighting, electroluminescence offers: (1) a means of minimizing extraneous light, and (2) excellent sharpness and clear definition.

Edgelighting employs the phenomenon of total inner reflection which occurs in plastic and other transparent media. Once the light is directed into the plastic, it flows until it is interrupted by disruptions in the plastic surface. These disruptions are the numerals, letters, and graduations which are engraved in the plastic and filled with paint (see Fig. 2). This method provides greater control of the light and the lighting of the engraved numerals and graduations and is superior to that achieved in floodlighting. However, the pointers must still be floodlighted and thus the objections mentioned above regarding floodlighting remain.

"Black lighting" is a misnomer. It is more properly described as ultraviolet lighting. Glass filters are usually placed over the bulbs, and phosphor paints are used on the numerals, graduations, and pointers. The filter removes most of the visible light and transmits the ultraviolet and some visible blue. The phosphor paint fluoresces when activated by the blue and near ultraviolet and thus the numerals, graduations, and pointers are seen. Since most of the visible light is filtered from the system, the deficiencies noted for floodlighting are minimized.

Although "black lighting" produces a very desirable effect, electroluminescence is considered superior in several respects: (1) illumination level; (2) panel effectiveness not diminished by phosphor depreciation; (3) absence of stray light.

In comparison with the three lighting methods mentioned above, electroluminescence has the further advantage of being adaptable to the variety of desired instrument panel shapes, along with the design flexibility to accommodate the necessary internal constructions of the various panels. The typical sections of instrument panel components

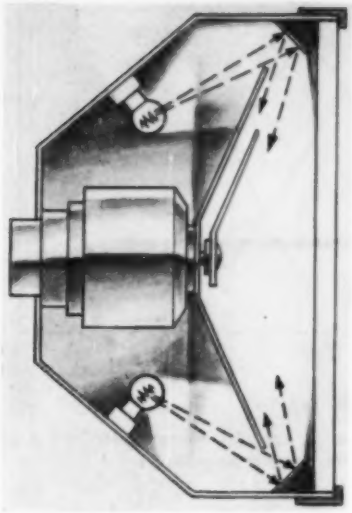
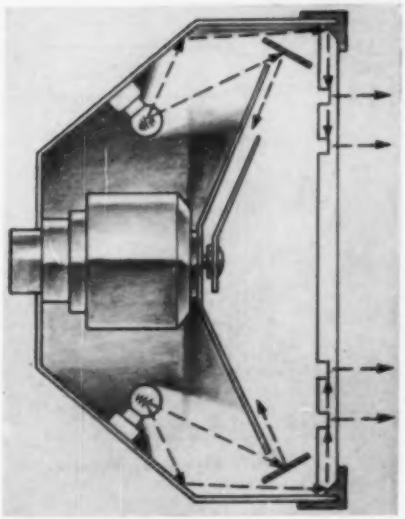


Figure 1 (left). Floodlighting a speedometer.

Figure 2 (right). Edgelighting a speedometer.



shown in Fig. 3 emphasize the variety encountered. In spite of these variations, the lighting of each component must be compatible with the others in both color and intensity. With electroluminescence, the desired objectives can be attained quite readily.

Electroluminescence

Electroluminescence has come to be a generic term. It is defined as the mechanism by which light flux is generated when a phosphor is directly excited by an alternating electric field. The application of this phenomenon to automobile instrument lighting is new. Among the several different laboratory and commercial forms which an electroluminescent lamp may take, ceramic on metal has been currently adopted for automotive use. The ceramic on metal lamp has the characteristic physical appearance of a parallel plate capacitor. In its simplest form the panel is flat. Where curved surfaces are required, the panel can be formed, using common sheet metal working techniques, to any reasonable shape. The fundamental construction of a typical ceramic on metal panel is shown in Fig. 4.

(1) The metal is cold rolled sheet steel and is nominally .030 inch thick.

(2) The ceramic ground coat applied to the steel acts as a glass-to-metal seal and sets up proper electrical characteristics.

(3) The second coat is the phosphor bearing ceramic material which glows in the presence of an alternating electric field.

(4) Upon the phosphor coating a thin film of transparent conductive material is applied.

(5) The final coating given to the lamp is a vitreous film which covers the entire surface and

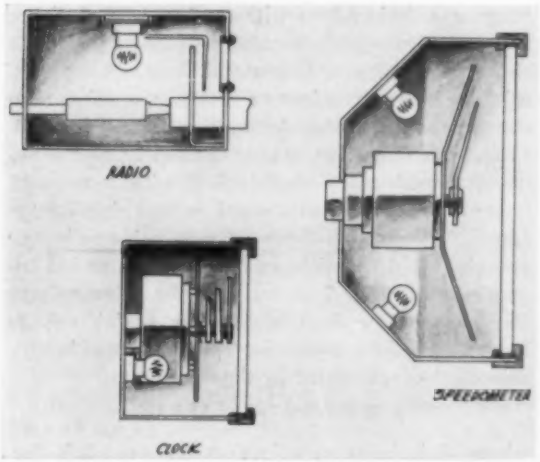


Figure 3. Typical sections of instrument panel components.

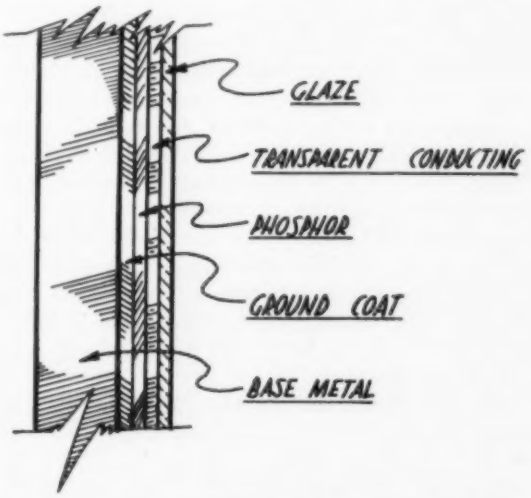


Figure 4. Layers of an electroluminescent lamp.

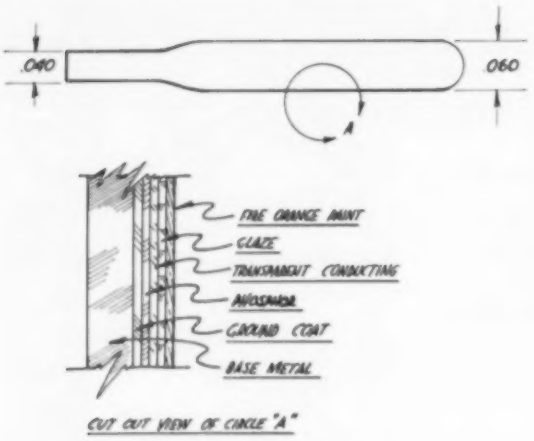


Figure 5. Pointer.

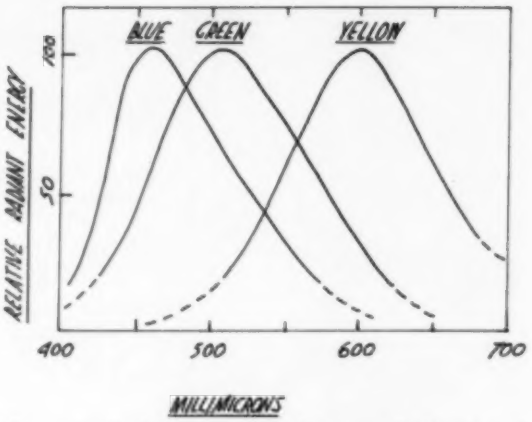


Figure 6. Variation in spectral energy distribution of emitted light for three typical phosphors.

edges of the lamp. The purpose of this film is to insulate the panel electrically, and more important to hermetically seal the panel from any moisture effects. This construction has the physical strength, moisture protection, long life, good maintenance and reliability needed for automotive application.

A modification of the conventional flat form of the electroluminescent lamp is offered by slender cylindrical shapes. These are often used as pointers. They are of similar construction to those formerly described but the coatings are applied as concentric layers. Fig. 5 shows the construction of the pointers. A typical pointer is made of .040-inch wire with coatings built up to about .060 inch. It is given a final coat of red fluorescent paint to provide a thin line of red light for easy identification.

Lamp Characteristics

Since the electroluminescent lamp is an alternating current device, it can be operated with a wide range of frequency, voltage and wave form. The amount and color of the emitted light, though primarily determined by the phosphor, are also influenced by the dielectric medium and power applied.

Among presently available electroluminescent phosphors which provide reasonable light-generating efficiency, zinc sulfides activated by copper are considered outstanding. Control of the copper content allows either blue or green emission to be obtained at will. Addition of manganese, in increasing amounts, gradually suppresses emission at the shorter wavelengths, with development of emission at longer wavelengths in the yellow-orange portion of the spectrum.

Fig. 6 indicates the variation in the spectral energy distribution of the emitted light for three typical phosphors. Other colors can be obtained by overcoating the lamp (by this means an organic phosphor will give excellent reds) or by using phosphors modified by the addition of selenium. These particular energy distributions are obtained with specific phosphors when the lamp is operated at 400 cycles per second. As the alternating current frequency increases from 100 to 1000 cycles per second, the emitted light changes color, toward the blue end of the spectrum. At higher frequencies, there is little or no additional color change. In further discussion of lamp characteristics the behavior of green lamps will be indicated, since blue and yellow lamps generally show a parallel behavior, though with some minor variations. The surface brightness and total light emitted by an electroluminescent lamp are strongly dependent on frequency and voltage applied, as shown in Figs. 7 and 8. It would be more precise, though less convenient in practice, to say that the brightness at a given frequency is determined by the voltage gradient or electric field between the two parallel electrodes. In manufacture, electroluminescent lamps are designed to withstand a voltage either 25 per cent above their rated voltage or 100 volts above rated voltage. Because of these two separate criteria, it is convenient to divide lamps into two classes, the first being low-voltage lamps for 120- to 250-volt operation, where the safety factor demands a rather low electric field with consequent lower brightness; the second being high-voltage lamps, for operation above 400 volts, where a higher electric field is possible and where greater brightness results. Fig. 7 shows data for a low-voltage lamp, while Fig. 8 gives data for a high voltage lamp at selected frequencies. These curves of brightness can be represented by the equation

$$B = cf^a \exp\ (-bE^{-\frac{1}{2}})$$

where B is brightness in footlamberts; f is frequency in cycles per second; E is volts per mil of thickness; and a, b, and c are constants dependent

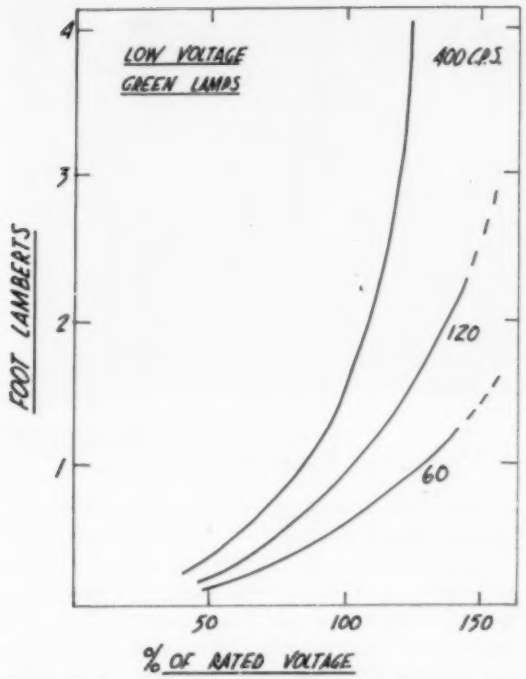


Figure 7. Low voltage lamp data at selected frequencies.

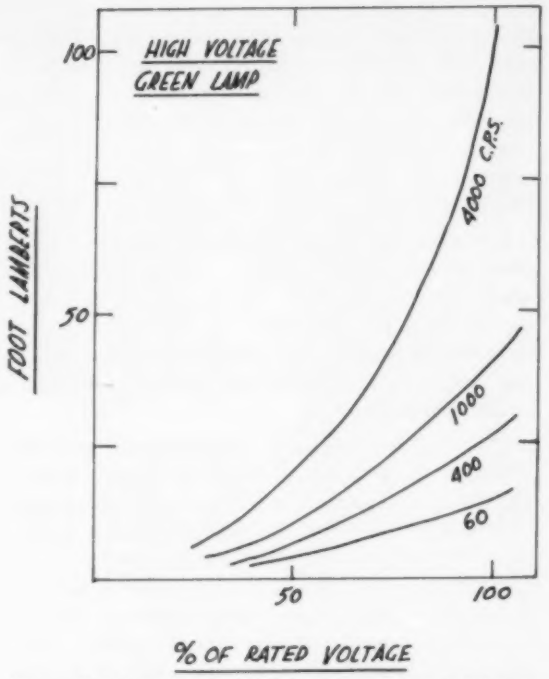


Figure 8. Data for high voltage (over 400 volts) lamp.

on phosphor and dielectric properties (a is usually within the range 0.50 to 0.75).

The electroluminescent lamp has the character of a condenser, but with appreciable power consumption. The power factor is the ratio of watts, determined on an electronic wattmeter, to the product of volts and amperes, determined as root-mean-square values. Because of the distortion of wave shapes, phase-angle meters give unreliable results if used for measurement of the power factor of these lamps.

The usual lumped-constant equivalent circuit will not adequately describe the electrical properties of the electroluminescent lamp, since both the capacity and the resistance appear to be nonlinear functions of voltage. Instead of a phase shift of the current with respect to voltage as the power factor changes, a distortion of the current wave shape occurs, with the gradual appearance of an in-phase current component as the applied voltage is increased. The light output, however, remains nearly 90 degrees out of phase with the voltage and shows no phase shift.

Fig. 9 displays the current as a function of instantaneous voltage. In this diagram the unshaded areas indicate the period when the lamp is absorbing power, while the shaded areas represent a release of stored energy. The resemblance to a B-H hysteresis loop obtained with magnetic materials is rather striking, though field limitation rather than current saturation occurs, in contrast to the flux saturation at high field strengths evident with magnetic materials.

As an approximation, it is possible to consider an electroluminescent lamp as a nonlinear impedance, the relationship between current and voltage being:

$$I = ZV^n \quad (n = 2 \text{ to } 3).$$

The efficacy of the commercial electroluminescent lamp, when considered as a light source, is relatively low. Commercial lamps will normally have efficacies of 1.0 to 2.0 lumens per watt in contrast to incandescent lamp efficacy of 10 to 20 lumens per watt and fluorescent lamp efficacy up to 75 or more lumens per watt. Design compromises can increase

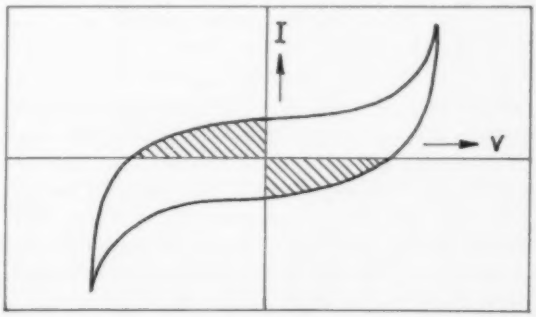


Figure 9. Current as a function of instantaneous voltage. Unshaded areas indicate period when lamp absorbs power, shaded areas represent release of stored energy.

commercial efficacy to 5 lumens per watt if power limitations require this. By accepting a low brightness and designing for the voltage and frequency which will produce maximum efficacy, an electroluminescent lamp can be made to produce 10 lumens per watt.

Power Supply

For automotive applications, voltage is obtained from a transistorized oscillator which develops 200 volts at 250 cycles from the 12-volt d-c system in the automobile. The 200-volt, 250-cycle ratings were chosen because they give sufficient brightness and operating characteristics to satisfy the automotive requirements.

Design criteria for this power supply are: (a) Stability of operation with varying input voltage; (b) Frequency which will give high light output and still not interfere with any surrounding electronic equipment; (c) Minimum size and cost.

Two modes of operation are possible. The more common, a typical square wave switcher, gives essentially a square wave and depends largely on the saturation of the iron in the transformer. Limitations are relatively low efficiency and the fact that in square wave operation the leading edge consists of many sharp peaks which tend to break the lamp down and cause radio interference. This method was abandoned in favor of a sine wave oscillator which is a more efficient device because of its low core losses. Providing essentially a sine wave with no peaks, it causes no radio interference. By properly matching the transformer to the transistor, it is possible to double the power handling of the system over the square wave type of oscillator. A carefully chosen airgap in the transformer gives a relatively high "Q." Two additional resistors are employed to stabilize the drive and to bias the transistor for starting. A frequency of 250 cycles was chosen to keep the frequency in the low audio region and to permit the use of readily-available core materials. Over-all efficiency is over 90 per cent.

A typical automotive power supply has these characteristics (see Fig. 10): With a nominal input voltage of 13.2-volts d-c and a nominal dummy load having an impedance of 11.3k ohms and 65-degree phase angle current leading, the primary current is 0.9 ampere. The output is 200 volts rms ±30 volts at 250 cps ±50 cps. Output current is 18 ma rms although the supply is capable of delivering much more. Short circuit current is 1.3 amps d-c. The supply will start and operate satisfactorily throughout the voltage range of 10.5-volt d-c to 16.2-volt d-c with a load impedance range from 7.5k ohms to 14.7k ohms at phase angles between 55 degrees and 80 degrees (current leading) in an operating temperature range of −20F to +125F (ambient temperature 72F).

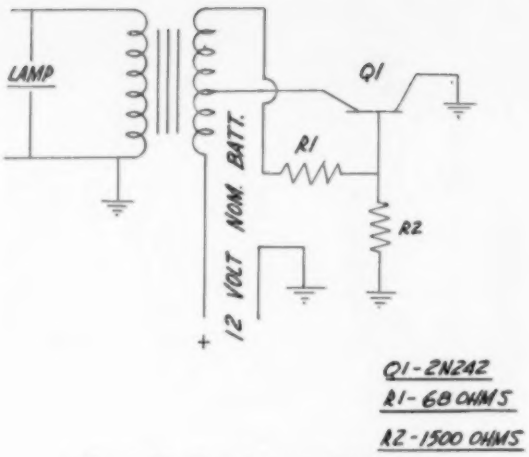


Figure 10. Transistor oscillator circuit.

There are several possible approaches to the use of electroluminescence in automotive lighting. A first approach is to use flat panels themselves to floodlight the pointers and dials. This is similar to the present floodlighting techniques used except that the low brightness electroluminescence would avoid the glare normally associated with point sources of light and give more uniform lighting. Another method is to make the dial an electroluminescent lamp with applied opaque numbers and letters. With this the numbers, letters, and pointers are seen in silhouette. A more satisfactory and dramatic approach is to light only the parts of the panel to be seen, the numbers, letters and pointers. This satisfies the fundamental requirements for good panel lighting. The message is transmitted rapidly with no extraneous light and there is no glare associated with the panel. Since the driver is looking only at the letters, low brightness can be used so that he can adjust for driving conditions. Circuitry is provided so that lighting level may be increased or decreased to suit individual needs.

Since the surface of the panel is completely lighted and it is necessary to mask out all but the letters and numbers, this mask or overlay must be attractive in the daytime. Furthermore, it must be opaque to eliminate all of the unwanted light from the electroluminescent source. To satisfy the daylight requirements and also to harmonize with the color scheme of the automobile, it is necessary to provide the correct overlay. The technique of using the overlay permits a wide variety of color selections, numbering and lettering schemes.

There were several instrumentation techniques which had to be mastered in order to use electroluminescent lighting. Since the gauges are low torque instruments and the electroluminescent

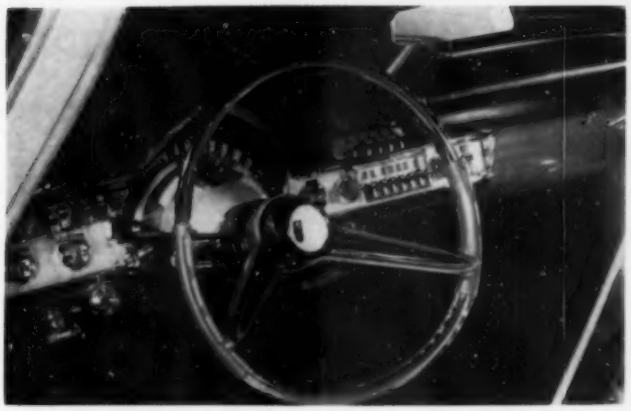


Figure 11. 1960 automobile instrument panel.

pointer is heavier than normally used types, balancing considerations required careful attention. Since the pointer also becomes a light source, a flexible lead wire delivers power to the pointer so that it does not interfere with the normal function of the gauge. To further improve the conspicuity, red phosphorescent paint is sprayed on each pointer to give it a distinctive red color. Speedometers are high torque instruments and can easily accommodate the electroluminescent pointer. The power connection to the speedometer pointer is similar to the gauge pointer connection. Clocks require special treatment. In this case the power must be delivered to the clock hands which necessarily rotate through 360 degrees many times. This is accomplished by the use of commutator rings. Power is taken from the panel and delivered to the commutator rings of the hour and minute hands through small coil springs which also serve to hold the hands in place. The radio and switch title lighting is treated in a conventional manner by delivering power directly to each panel.

Shown in Fig. 11 is a picture of a 1960 automobile instrument panel. This panel has several styling and design features which have been made possible by the electroluminescent lamp. The astrodome with its cluster of instruments is the center of interest.

Absence of glare-producing extraneous light was essential in a design of this configuration. Furthermore, with electroluminescence, stray light from the edges of the dome is negligible. In fact, at night the dome is virtually invisible.

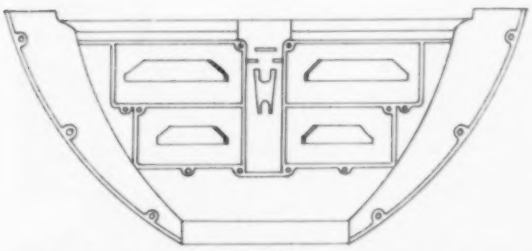


Figure 12. Bottom view of inner dome, instrument cluster.

A significant design feature can be appreciated by reference to Fig. 12 which shows a bottom view of the inner dome of the cluster. Since electroluminescence is a cold lamp, which does not heat surrounding areas, the inner dome can be a single molded plastic piece.

Had the light sources contributed any considerable amount of heat, the astrodome would have been an assembly of several metal and molded plastic parts. Obviously, the single molded part offers appreciable economy.

Another design feature of the cluster is the manner in which the gauge pointers protrude from the inner dome. With its advantageous characteristic of avoiding extraneous light, electroluminescence facilitated a design which made possible the striking nighttime appearance of the clear astrodome.

The Future

Electroluminescence makes a major contribution to the science and practice of instrument lighting. The science can be applied to each new automotive design so that the engineer may obtain the most suitable light and know what results he will get with the panel without trial and error placement of individual lamps. He now has complete control over brightness, color, light intensity, configuration and the electrical circuitry. More important, electroluminescence will give a wide latitude to the stylist of the automotive dashboard. It will permit the use of new shapes, configurations and lighting effects. Furthermore, it will give the stylists the chance to include new features on the dashboard.

In the future, electroluminescence will not be confined to the dashboard. It will permit a host of other applications, both in the interior and on the exterior of the automobile.

INSTALLATION AT FRANKLIN PARK, ILLINOIS

Lighting a City Street

LIGHTING OBJECTIVE: To provide good roadway illumination in a city's business district to facilitate local pedestrian and vehicular traffic.

GENERAL INFORMATION: The curb-to-curb distance in this roadway installation varies from 40 to 60 feet. The pavement is concrete. An underground wiring system is provided throughout, consisting of a three-wire 240/480-volt system.

LIGHTING INSTALLATION: Line Material Industries Line 1B (IES type IV) street lighting luminaires, each equipped with four 72-inch T-12 cool white high output fluorescent lamps, are used throughout the project. The luminaires are mounted at a height of approximately 30 feet on American Concrete poles, which have two-foot bracket spans (see Fig. 2). A staggered arrangement of approximately 75 to 80 feet is used throughout. With this arrangement and the varied curb-to-curb distance, the resulting average illumination varies from 1.1 to 1.5 footcandles.

Figure 2. Daytime view of luminaire and pole.

Lighting designed by Edwin Hancock Engineering Company, 1409 W. Jackson Blvd., Chicago, Ill.

Lighting data submitted by Louis C. Odry, Line Material Industries, South Milwaukee, Wis., as an illustration of good lighting practice and to aid in the design of similar installations.

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Significant Advances in the Design of Non-Circular Cross-Section Fluorescent Lamps

By J. O. AICHER
E. LEMMERS

APPROXIMATELY three years ago a radically new, non-circular cross-section fluorescent lamp was introduced. This lamp has been found to be particularly advantageous in many lighting fields due to its high efficiency and high light output per foot of lamp. With lower first costs for the lighting system as compared to other fluorescent installations, and with the same or lower operating costs, it is becoming a popular system for general lighting. Installations such as shown in Fig. 1 have proven the practicability of this lamp design in obtaining higher lighting levels along with good efficiency and long life.

This original non-circular cross-section lamp established a plateau on which further developments in lamp performance could be applied. As always has been found to be the case with new design principles, further improvements are possible. In this case they have resulted in a non-circular T17 lamp of modified design which operates on present 1500 ma ballasts and, properly oriented, produces a 15 per cent increase in light output along with an 8 per cent increase in efficacy as compared with the original lamp. This has been accomplished by the application of the same principles that were brought out in the original paper.[1] Summarized briefly, these are:

(1) Electron temperature is increased, resulting in more effective production of excited mercury atoms.

(2) Voltage gradient is raised, making it possible at any given current to put more energy into the arc, per foot of the lamp's length, with increased efficiency as described below.

(3) Relative wattage expended at the electrodes is reduced for any given lamp current, or in other words, absolute electrode wattage losses are reduced at any given value of lamp wattage because of the resulting lower current.

(4) Opportunities for energy-dissipating proc-

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 7-11, 1959, San Francisco, Calif. AUTHORS: Large Lamp Dept., General Electric Co., Cleveland, Ohio. Accepted by the Papers Committee as a Transaction of the IES.

Figure 1. An installation in the 200-300 footcandle range. Worker efficiency is improved 10 per cent; spoilage and minor accidents are reduced 20 and 50 per cent. Only 3 per cent of the lamps had failed at 6000 hours of burning (16 hours per start). It is reported that the installation paid for itself in three months.

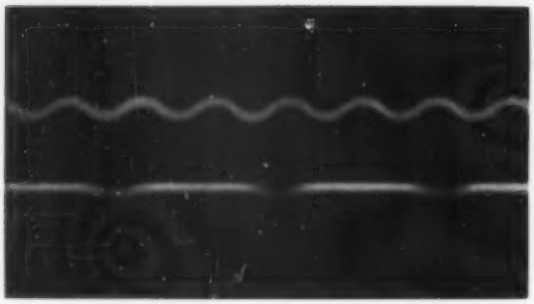

Figure 2. Comparison of arc behavior in old and new lamp designs.

esses to occur are minimized because of the smaller concentrations of both electrons and excited atoms. Yet the effectiveness of production and delivery of the necessary 2537Å radiation at the walls, is enhanced.

(5) The ratio of energy lost through elastic collisions, to the energy (as 2537Å) received at the bulb wall is very appreciably reduced because of the use of fewer electrons at higher electron temperature.

New Bulb Geometry

The improvement in performance is due largely to a new bulb design. Fig. 2 shows the new design above, the earlier version below. These are photographs of clear, uncoated lamps, and show the appearance of the discharge. In the original lamp there were zones of circular cross-section approximately every ten inches along the lamp's length (eight zones in a 96-inch lamp). These were necessary to strengthen the bulb, but were undesirable inasmuch as they were zones of reduced light output as is suggested by the fainter appearance of the arc. If a groove could be placed in these zones, on the opposite side from the main grooves, both wattage and efficiency would be increased without impairing the ability of these zones to strengthen the bulb. New developments have now permitted forming grooves on both sides. In the new lamp the grooves on both sides are all equal in length, much shorter and more numerous than in the old design. Shortening of the grooves has permitted reduction in glass thickness sufficient to reduce the lamp's weight by 25 per cent, while maintaining the same strength.

Another very desirable feature of the larger number of grooves, alternating from side to side, is an increase in length of the arc stream as is readily seen here (Fig. 2). In a 96-inch lamp, there is approximately the equivalent of an extra foot of lamp length. This is highly desirable since it increases lamp operating voltage, enabling wattage to

Figure 3. The very desirable shape of the cross-section of the many "transition zones" by which extra arc length is achieved.

be increased without increasing current. This longer arc length makes effective use of the very efficient "transition zones" which more fully utilize the advantages of non-circular geometry in making the arc go from grooves on one side to grooves on the other. Fig. 3 shows the shape of the transition zone cross-section in which the arc behaves much as if it were in the very desirable oval-shaped bulb. These regions are so designed that the arc remains stably in the central space. The presence of the enlarged portions at the ends of each such cross-section provides the necessary I-beam type strengthening of the lamp.

The cross-section of the groove has been changed, as will be seen in Fig. 4. This shows, to scale, the earlier design on the left, and the new shape on the right. The new design of groove is more open and allows more light to escape directly than was possible with the previous design, as indicated in the figure.

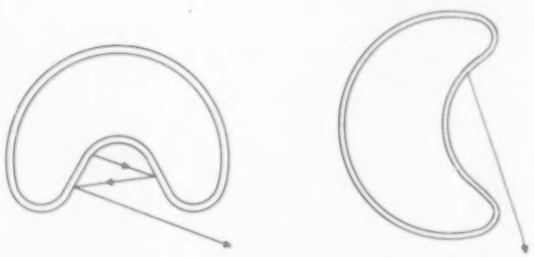

Figure 4. Shape of cross-section of main grooved portion in original lamp (left) and improved lamp.

Factors Affecting Wattage

By itself, this more open arc space tends to reduce lamp wattage, but this effect is more than offset by a combination of factors that increase lamp wattage. One such factor is the previously mentioned very effective utilization of a longer arc.

Another factor is the reduced mercury vapor pressure, made possible by the presence of specially designed portions of the bulb. Although the degree of reduction realized has practically no effect on luminous efficacy, it increases wattage of the lamp without raising starting voltage. This reduced mercury vapor pressure warrants considerably more discussion, first from the standpoint of the method of its attainment, and later, as it affects lamp measuring procedures.

Methods of Controlling Mercury Vapor Pressure

If one groove is made slightly deeper, and asymmetric as in Fig. 5, and the lamp is operated with the sharper portion of this groove down as shown, the arc, in following the path of least resistance will go through the more open portion at the top. The normal circulation of cool air upward past the sharper portion, along with absence of the arc from this part of the cross-section maintains a temperature of approximately 40C at this point under standard test conditions.

Since, in an a-c discharge of this type, the mercury has a slight tendency to migrate to the center, the temperature control zone (the asymmetric groove) was placed near the center to take advantage of this phenomenon. The lighted appearance of the asymmetric control zone is so nearly like that of the rest of the lamp that it is virtually unnoticed. The lamp could, therefore, be installed so that this groove is upside down, rendering it ineffective. To prevent this difficulty, a similar, but reversed zone is also provided nearby, on the opposite side, so that one properly operating control zone will be present regardless of the orientation of the lamp as long as the lamp is in a substantially horizontal position. The cool zone contributes to the increased wattage of the lamp by providing a minimum bulb temperature closer to the optimum value for light output than in the case of the earlier design. In addition it provides suitable mercury temperature control without the presence of a portion of the lamp's length having reduced wattage or luminous efficacy, as in the earlier lamp.

Summary of New Lamp Design Parameters

(1) The bulb strengthening zones which had a circular cross-section in the earlier lamp have been changed in a manner which improved the lamp by simultaneously increasing both wattage and luminous efficacy.

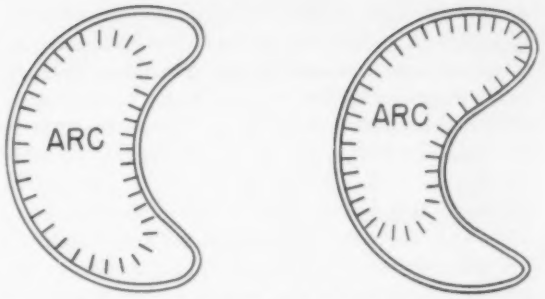

Figure 5. Comparison of normal groove cross-section shape with that of the mercury control zone (at right) by means of which mercury vapor pressure is maintained at a desirable value without a loss of lumens or of luminous efficacy.

(2) Use of shorter grooves, on opposite sides, has permitted reduction of bulb weight by 25 per cent, while maintaining strength.

(3) A change in cross-section shape has further raised luminous efficacy by facilitating escape of light.

(4) By proper design of two of the grooves, almost invisible mercury control zones have been established.

Effect of Temperature on Performance

The effect of temperature on the performance of this new lamp is of importance. As with all fluorescent lamps, and especially with those that are highly-loaded, the electrical characteristics are very much a function of the mercury vapor pressure within the lamp. Fig. 6 shows relative wattage, light and luminous efficacy values of a 96-inch lamp operated at 1.5 amperes (linear choke, 400-volt circuit) with the temperature of the coolest

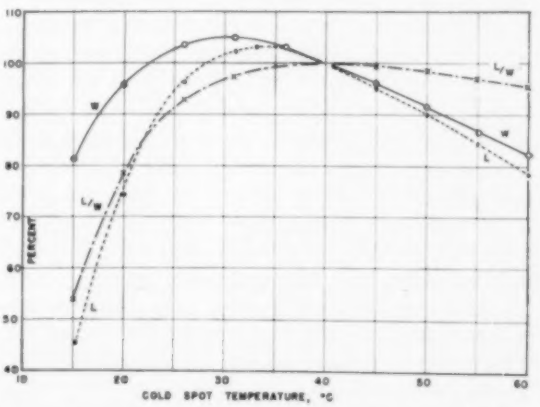

Figure 6. Relative light, wattage and luminous efficacy characteristics of the 96-inch lamp as a function of cold spot temperature.

spot controlled at various temperatures between 15 and 60C. All liquid mercury was condensed at this cold spot (a condition that ultimately prevails in burning). The 100 per cent point was taken at 40C, which is the control spot temperature that is attained under the industry standard photometric conditions of still air at 25C (77F). The actual values at this rating point (grooves sideways) are 175 volts, 215 watts, 15,000 lumens and 70 lumens per watt. It will be seen that light and wattage are affected together so that luminous efficacy remains above 95 per cent of rated value for control spot temperatures between 28 and 60C.

Evaluation of Performance

In doing development work on a new lamp of this type it is necessary to make precision measurements of lamp performance. It has been found necessary to operate the lamp long enough so that all liquid mercury collects in the coolest part of the bulb for the particular lamp position and environment under test. It cannot be determined by visual inspection whether all of the mercury has migrated to the cold spot. If all of the condensed mercury is not at the cold spot the lamp will not be completely stabilized. Lack of such complete stabilization, although important in making precision measurements, is not even noticeable in a customer's installation, since it affects lamp wattage and light by only a few per cent under normal ambient conditions. It is reasonable to expect that upon overnight burning, randomly placed mercury will condense temporarily in the cool areas associated with the many normal grooves. With the lamp operated in 77F still air and with the grooves sideways, wattage and lumens reach 95 per cent of the stabilized value. With grooves facing up and down, the value is about 90 per cent. Upon longer burning, this temporarily located mercury will move to the true control area where the full rated performance is obtained with grooves sideways and approximately 95 per cent of this value with the lamp turned on its axis 90 degrees. It should be emphasized that lamp efficacy does not fall more than 1.5 per cent under the worst of any of the above conditions.

If drafts are present, some other portion of the bulb may control the mercury vapor pressure, and this condition does not necessarily result in a less desirable performance. It does mean, however, that lamps completely stabilized under one set of ambient conditions may not necessarily provide stable performance immediately after transfer to other ambient conditions.

No single figure can be given for the length of time required for true stabilization because of the numerous factors which must be considered. These are:

(1) The amount of mercury to be transferred, in the vapor phase, to the control spot.

(2) The distance the mercury must be moved in arriving at this control spot.

(3) The difference between vapor pressure of the mercury in the warm and in the cool portions. This involves not only the difference in temperatures, but also the actual temperatures for any given differential.

For example, a lamp in which a small amount of mercury has to move only a few inches to the cold spot, if burned in a warm ambient, may adjust in a few hours of burning. A typical time required for initial stabilization under standard rating temperature conditions may be about 150 hours. It is very useful in measurement work, to elevate the temperature of all parts of the lamp, except the mercury control area, by suitable covering or jacketing to hasten the adjustment process.

Mercury droplets condensed under usual conditions are generally numerous and quite small and adhere well to the coating, so that the lamp can be moved for measurement if handled carefully. Local, forced cooling at the cool spot by means of contact with a piece of metal conforming to the shape of the bulb and contacting it over an area measuring approximately ½- x 1-inch is also effective. A very simple and satisfactory procedure for determining whether a lamp is completely stabilized is to cool it with a piece of ice in the small area where mercury has collected. If all of the liquid mercury is properly collected, the lamp's light will rise slightly at first and then will fall off severely within a short time due to mercury starvation. After removal of the ice full recovery occurs just as rapidly. If only a relatively small change occurs, there is still liquid mercury not yet localized in the cool spot.

Lamps and Ratings

As in the case of the earlier lamp, this one is also a rapid-start type. These are available in 48-, 72- and 96-inch lengths, at present, in the standard cool white color. With this new design, employing the

TABLE I — Comparison of Three Non-Circular Cross-Section Fluorescent Lamps.

Lamp Length (Inches)	48	72	96
Total Grooves	18	29*	40
Open Circuit Voltage	300	350	400
Lamp Current, Amperes	1.50	1.50	1.50
Lamp Voltage	85	125	175
Lamp Wattage	110	160	215
Lumens at 100 Hours	6900	10900	15000
Lumens Per Watt at 100 Hours	63	68	70

*14 grooves on one side, 15 on opposite side.

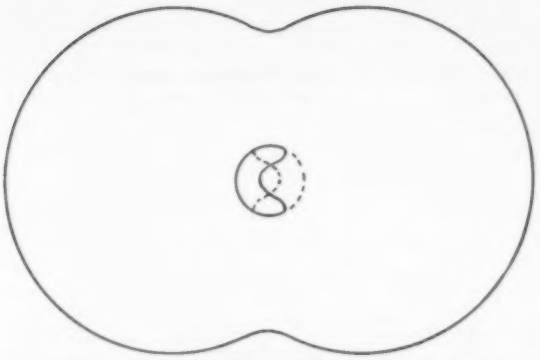

Figure 7. Light distribution pattern of the new lamp.

shorter groove length, exactly the same geometry has been used in all sizes except for lamp length. All three sizes have the previously mentioned two potential control areas, separated by two regular grooves. Table I summarizes characteristics of the three sizes, measured on a sine wave supply with linear reactor ballast but without separate heating of the cathodes at the time of measurement. Most recent measurements indicate that the 48-inch lamp operates at 112 watts, yielding over 7000 lumens, and that the 72-inch lamp operates at 162 watts, yielding 11,000 lumens.

This new lamp produces a symmetrical "two-way" light distribution (Fig. 7) very similar in shape to that produced by the original lamp. This directional distribution permits the designer of a fixture to position the lamp in the orientation which is best for that particular fixture. Basing is the same as for the previous lamp, and in existing installations the grooves on one side face the same direction as before. For best lamp light output the grooves should face sideways as has been mentioned. Obviously, in new luminaires the sockets or lamp-holders may be positioned as desired, considering the light output of the lamp-luminaire combination.

Summary

The extension of the original principles of non-circular fluorescent lamps by means of the improved bulb geometry has resulted in a further increase in light output and luminous efficacy, while at the same time reducing lamp weight.

The improved lamps will contribute greatly toward making it easier to obtain the higher levels of illumination recommended by I.E.S. They will give the user greater value, and contribute to the forward progress of lighting.

Reference

1. Aicher, J. O. and Lemmers, E.: "Design and Characteristics of Fluorescent Lamps Having a Non-Circular Cross-Section," ILLUMINATING ENGINEERING, Vol. LII, No. 11, p. 579 (November 1957).

DISCUSSION

C. J. BEANIER:* The new design of modified non-circular cross-section lamps seems to reduce the light producing effectiveness of the grooved portions of the lamp and improve that of transition zones. Since transition zones in the original design were relatively short, it is difficult to see where a net gain in lumen output is obtained.

In comparing the new lamp with the original, the question arises whether the increase in positive column wattage is not a result of the reduction in mercury temperature obtained by the use of mercury control zones rather than the increased arc length of larger effective diameter. In other words, is the positive column efficacy of the new lamp greater than that of the old when mercury temperature is 40C in both?

The authors show that luminous efficacy is optimum at approximately 40C cold spot temperature (Fig. 6). I would like to ask if this maximum coincides with a still air ambient temperature of 77F. (Our measurements indicate that the ambient must be somewhat below 77F to obtain rated lamp wattage.)

There is no word of lumen maintenance. Will the new design materially help the lamp's maintenance problem?

The modifications of the lamp have produced interesting, if not startling results in the light source's appearance. It seems that gains are being made in the direction of improved efficacy. However, it is doubtful whether the new source will contribute to better lumen maintenance or better utilization of light output.

G. P. WAKEFIELD:** This paper is of considerable interest as it represents something new in lumen generation—the basis of our profession. Two questions in the general field of maintenance and shaped sectional tubes arise:

(1) In maintenance, is there field experience to possibly justify the extra cleaning time required for these tubes vs. improved efficacy gained by using non-circular tubes. This may not be the intended scope of the paper, but the subject does occur.

(2) It appears as though we are approaching an era of directional-flux shapes. If this is so, considerable advances may be made by combining lumen generation with brightness control in the form of simplification and consequent cost reduction of better lighting.

C. L. AMICK:† This paper answers many questions about the new shape of T17 extra-high-output lamps. However, there are a few points which can be clarified.

(1) What are the light output, efficacy and wattage values of the lamps using the new bulb geometry when positioned with the grooves at various angles between sideways and up-and-down? This information would enable fixture manufacturers to better explore optimum orientation from standpoints of over-all cost of light and visual comfort. Our studies show that some luminaire types give the customer more light for his money with grooves crosswise; others are more economical with grooves up-and-down.

(2) The maximum light output appears to result with an ambient temperature of around 65F. Could the authors give a complete graph of per cent light output and wattage vs. ambient temperature for operation with grooves sideways and with grooves up-and-down?

(3) The paper explains that overnight burning (12 hours

*Sylvania Electric Products, Inc., Salem, Mass.
**The Wakefield Co., Inc., Vermilion, Ohio.
†Day-Brite Lighting, Inc., St. Louis, Mo.

or more) gives 95 per cent of stabilized light output. Does this mean 95 per cent of rated light output? We assume that in a typical installation, the rated light output is reached quickly after each start, once the lamps have been operated long enough for the mercury to initially reach the true control area.

G. C. HARVEY:* The authors' report of increased light output and efficacy of the new design over their original design is evidence of significant progress. Measurement methods by various groups within the lighting industry frequently differ to the extent that when one considers the instability of a fluorescent lamp, and even more so, the nature of heavily loaded lamps, it should be interesting that one ballast manufacturer has obtained data which compare favorably when using the more simple measurement methods employed in ballast testing. Comparative tests under stable conditions of lamp environment and testing methods on original and new standardized lamps also gave us approximately 15 per cent increase in light output while using the same reference and test ballasts.

From the point of view of the ballast designer, the type of fluorescent lamp design described here is especially desirable. It reduces the function to be performed by the ballast, since the lamp operating voltage has been increased without the starting voltage being increased. Certainly lamp designers should be encouraged to continue in this direction to the point where lamps extinguish at a minimum line voltage or input voltage consistent with acceptable lighting system reliability and reasonable electrical power system regulation.

The authors referred to the need for careful stabilization for measurement which involved a long period of conditioning time, care in handling or movement of standard lamp and carefully controlled environment, such as freedom from drafts. Heavily loaded lamps have a very fickle nature unless extreme care is used in controlling all these factors. This makes ballast testing very difficult and time consuming. To overcome this obstacle so that more consistent and economical testing can be done, work has been done to control, more critically, the method of obtaining and maintaining mercury pressure. A report of this work by W. W. Brooks[1] includes a Fig. 2 which depicts the benefit of forced pressure control when the lamp is subjected to conditions often found in ballast testing laboratories. For example, the first and second breaks show effects of voltage variation; the third one, the effect of drafts. With this control method, results are readily repeatable and by modification of the controlled temperature, lamps can easily be made to operate at their standardized ratings.

1. Brooks, W. W.: "How to Improve Ballast Testing," ILLUMINATING ENGINEERING, Vol. LIV, No. 10, p. 647 (October 1959).

J. O. AICHER AND E. LEMMERS:** In reply to Mr. Bernier, the transition zones in the original lamp were fairly long and amounted to about 25 per cent of the total positive column. This, coupled with the very low wattage and efficacy of the round cross-section, resulted in appreciable losses. The new tube has very high wattage and efficacy in the transition zones, amounting to about 50 per cent of the total positive column, thus raising watts and efficacy.

Changing from 45C mercury control to 40C accounts for only one-third of the gain realized. The new lamp positive column is more efficient than the old when both are at a 40C mercury control temperature.

Measurements of lamps of current manufacture reach rated watts in still air at 77F if conditioned as has been thoroughly discussed in the paper. The watts are taken without cathode heat which has been our standard practice for rapid-start lamps.

All 25-watt-per-foot lamps have a lower maintenance than 10-watt-per-foot lamps. In our tests, the non-circular lamps, in general, have enjoyed a better maintenance than any of the other types of 25-watt-per-foot lamps. The new lamp, even though it has edged upward to almost 27 watts-per-foot is showing maintenance higher than the older lamp. Tests show as high as 84 per cent at 3000 hours, obtained under standard testing procedures. With an argon-filled lamp, such as the new lamp is, factors other than the bulb shape can have a major effect on maintenance. Along with the improved maintenance being realized, we are also, as Mr. Harvey has pointed out, experiencing a 15 per cent gain in output where the new and old types are compared under similar conditions.

In addition, there is an area which Mr. Wakefield has mentioned wherein the fixture may be made to obtain additional benefits by specifically designing to take advantage of the directional-flux radiated by these lamps.

On the subject of cleaning, we have not heard any complaints. We presume cleaning is slightly more time consuming. However, the costs of cleaning are small compared to the cost savings of increased lamp efficacy.

We agree that there are great possibilities in fixture design that will utilize the directional-flux characteristics of this lamp to provide improved lighting performance.

In answer to Mr. Amick's question of groove orientations between horizontal and up-and-down, wattage and output will be between 95 and 100 per cent of the groove-horizontal performance. Efficacy does not change.

Ambient conditions strongly involve air *motion* as well as temperature. Both items are a function of fixture design. For the still air, bare lamp condition, the information requested can be derived from the data of Fig. 6 of the paper, *i.e.*, the general shape of the curves will be the same and they will be displaced from the 40C point by the amount the ambient departs from the 77F value.

Ninety-five per cent of stabilized, or fully conditioned performance means 95 per cent of *rated* values of light output and wattage. As has been previously mentioned, efficacy remains at practically 100 per cent. In a typical installation the light output that is reached fairly soon after each start depends upon the degree to which the commercial ballast approaches the performance of the reference ballast. The time required for full conditioned performance is related to the time the lamp had been off, during which time mercury may move away from the control area.

We heartily agree with Mr. Harvey that a means for quickly conditioning highly loaded fluorescent lamps should be agreed upon. He mentioned one method used in the paper by Brooks. Another method is the use of only a small excess of mercury in test lamps. This is desirable in ballast testing, but *especially* in lamp and fixture work where no artificial operating conditions are necessary.

I would like to point out that in the illustration Mr. Harvey cited, the lower position of the conditioned lamp's light output curve simply indicates that this lamp is conditioned initially, providing full performance from the *beginning* and therefore it does not improve, as does the unconditioned lamp, upon burning.

*General Electric Co., Danville, Ill.
**Authors.

INSTALLATION AT HANSCOM BROTHERS, INC., PHILADELPHIA, PA.

Lighting a Bakery Shop

LIGHTING OBJECTIVE: To provide general illumination in an attractive manner for the merchandising of baked goods and candies.

GENERAL INFORMATION: In this store the total floor space of approximately 1000 square feet is used for merchandising. The area is 26 feet by 38½ feet with a ceiling height of 8½ feet. The front (shown in the right background above) and one side wall (center background) are glass window displays. Colors and reflectances of the major room surfaces are:

ceiling	white	75% RF	floor	terrazzo	20% RF
walls, back	rose	18% RF	columns	rose and	18% RF
side	yellow green	22% RF		yellow green	22% RF

INSTALLATION: An average level of illumination throughout of 100 footcandles is provided by the following luminaires, manufactured by Pittsburgh Reflector Co.:

6-catalog No. SS-84840 surface-mounted 4-foot square fluorescent units, each equipped with eight 40-watt T-12 cool white rapid start lamps. These are spaced as shown in Fig. 2. (Marked A)

(over)

A.I.A. File No. 31*f*

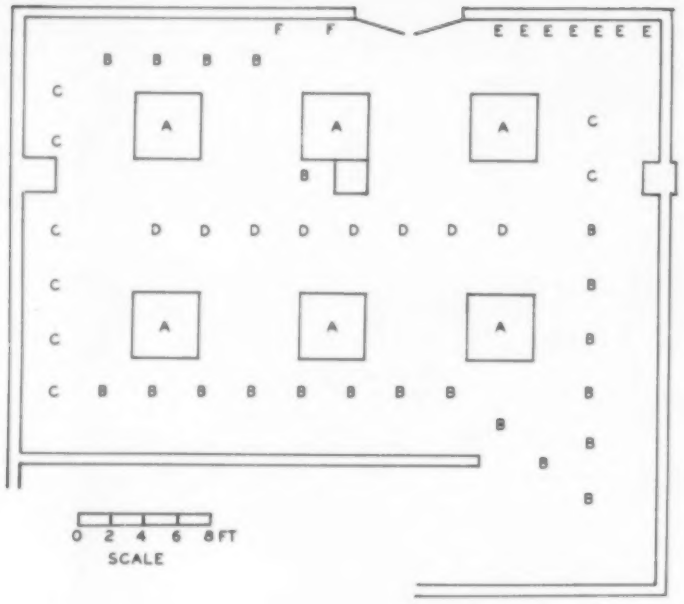

Figure 2. Plan view showing location of luminaires.

20-catalog No. 85-4 recessed asymmetric reflector units with hinged ceiling roundel, each equipped with one 150-watt A-23 incandescent lamp. These are symbol B in Fig. 2.

8-catalog No. E-220-4 recessed symmetric reflector units with hinged ceiling roundel, each equipped with one 200-watt incandescent lamp. These are symbol C in Fig. 2.

8-catalog No. E-230-4 otherwise as directly above but equipped with one 300-watt incandescent lamp. These are symbol D in Fig. 2.

7-catalog No. C-100-5 recessed symmetric reflector units with hinged concentric louvers, each equipped with one 150-watt incandescent lamp. These are symbol E in Fig. 2.

2-catalog No. I-100-5 otherwise as directly above. These are symbol F in Fig. 2.

Brightnesses at the time of illumination readings were:

luminaires		walls	
fluorescent at 45°	900 fL	back	9 fL
incandescent at 45° (roundel)	1600 fL	side	11 fL
incandescent at 45° (louver)	1200 fL	display cases	
ceiling	15 fL	horizontal	30 fL
floor	18 fL	vertical	15 fL

Lighting designed by Arthur V. Schafer, Philadelphia Electric Co., Philadelphia, Pa.

Lighting data submitted by Arthur V. Schafer and George T. Anderson, Jr., Philadelphia Electric Co., Philadelphia, Pa., as an illustration of good lighting practice and to aid in the design of similar installations.

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External Control of

Mercury Pressure of Fluorescent Lamps and its Application to Luminaires

By P. J. UNDERWOOD
C. E. BECK

This paper outlines the results of an investigation into a simple means of obtaining external control of mercury pressure of fluorescent lamps and how this method can be incorporated into new luminaire designs to increase light output, when the lamps are operated in higher than the normal ambient temperatures. Simple low cost cooling devices designed into luminaires were found to reduce effectively the mercury pressure, with gains of 8 to 18 per cent in light output in recessed troffers (for example) having ambient temperatures around the lamps of 112-140F.

Fluorescent Lamp Operation

Light output and performance of a fluorescent lamp vary with the surrounding ambient temperature. This is the result of a change in mercury pressure within the lamp. This pressure is determined by the coldest point on the bulb wall.

In fluorescent lamps, it is essential to have a small amount of mercury. During lamp operation, mercury is excited by the action of the arc and emits 2537 angstrom radiation, which, in turn, excites the phosphor crystals to emit visible light. It is not necessary here to cover this process in detail, since there are many good references covering the operation of fluorescent lamps.[1]

Mercury pressure within the lamp is determined by the coldest point on the bulb wall. The effect of mercury pressure on lamp characteristics, and means of changing them by varying the temperature of the coolest point on the bulb wall, will be considered.

Bulb wall temperature is influenced by lamp loading, bulb configuration, luminaire design, ambient temperature and draft conditions. In many cases more compact luminaires and higher footcandle levels and other new concepts in lighting have raised ambient temperatures in the vicinity of the lamps.

Fig. 1 shows the variation in lamp characteristics as the temperature of the cold spot is changed. The curves shown are for a highly loaded lamp operating at 1.5 amperes constant current. It should be kept in mind that there will be minor variations in these curves depending upon the ballast used, whether primary voltage or lamp current are held constant, and the lamp type involved. These curves do show that lamp lumens and luminous efficacy peak at about 90-100F, and that volts and watts peak slightly lower, at about 85-90F, cold spot temperatures. At these cold spot temperatures, mercury pressure in the lamp is about 3-6 microns. At higher or lower mercury pressures the decrease in light output is substantial, falling off more sharply on the low pressure side of the peak.[2,3,4,5]

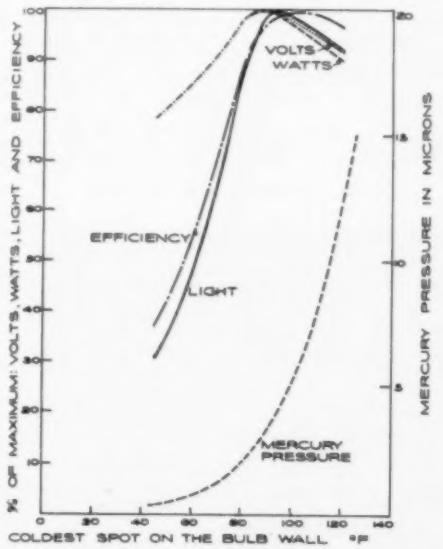

Figure 1. Lamp characteristics versus cold spot temperature of a highly loaded lamp at 1.5 amperes current.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 7-11, 1959, San Francisco, Calif. AUTHORS: Application Engineering and Discharge Lamp Design Engineering, respectively, General Electric Co., Cleveland, Ohio. Accepted by the Papers Committee as a Transaction of the IES.

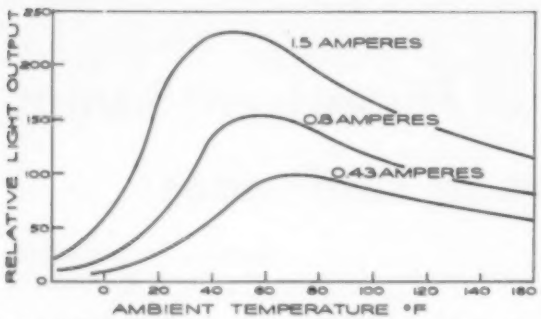

Figure 2. Light output versus ambient temperature of a 96T12 lamp at various currents.

TABLE I—Possible Per Cent Light Output Increases at Various Ambient Temperatures.

Lamp	Current—Amperes	77F	100F	120F
96T12	0.43	0	11	30
96T12HO	0.80	7	27	48
96T12HO	1.5*	17	39	58

*Almost double the design current.

In operation of conventional round lamps, 96T12 high output, for example, the coldest spot of the lamp is the bulb wall at approximately the center. This temperature rises with the increased lamp loadings.

Fig. 2 shows the light output curves versus ambient temperature for an F96T12 lamp operated in still air at different currents. The increase in current to the lamp has the effect of shifting the peak light output to lower values of ambient temperatures as the increased wattage to the lamp raises the bulb wall temperatures. If these lamps are operated in enclosed luminaires at room temperature, the bulb wall temperatures will rise and the light output will decrease; the curves are, in effect, shifted to the left. Drafts or forced air circulation around the lamps cool the bulb wall, shifting the curves to the right, the peak light occurring at higher ambient temperatures.

From Fig. 2 it can be theorized that appreciable light output gains can be made at the ambient temperatures shown in Table I, if the mercury pressure is kept at the optimum for the lamp.

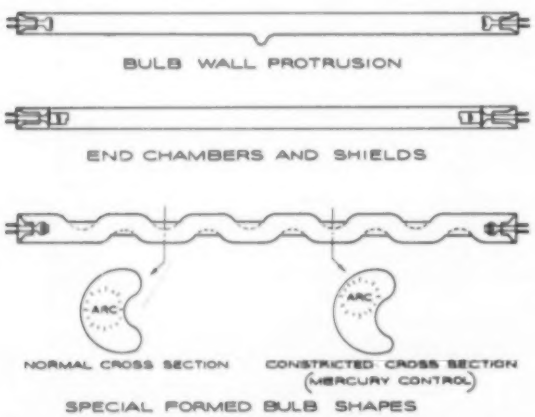

Figure 3. Methods of mercury control through lamp design.

Mercury Pressure Control—(Through Lamp Design)

Lamp manufacturers have recognized the importance of mercury pressure in fluorescent lamps and have designed lamps to give close to the maximum light output and luminous efficacy under the standard test conditions of 77F still air. With the trend to very highly-loaded lamps, special means of controlling mercury pressure have been developed as part of the lamp. Fig. 3 shows some of the methods employed by various lamp manufacturers.

These lamp designs result in a portion of the bulb wall operating at a temperature which is lower than that of the rest of the bulb wall. This cold spot operates at a temperature, which gives close to optimum mercury pressure under the standard conditions.

Mercury Pressure Control by Other Means

When fluorescent lamps are operating in ambients which cause higher than optimum mercury pressure, external means can be used to cool a portion of the bulb wall to a temperature which will give higher light output. Almost any heat transfer method can be uesd to produce localized cooling. Several possibilities are:

Air Jets
Fans and air conditioning
Evaporation condensation cycle devices
Cooling coils
Peltier thermoelectric effects

While all of the above methods are possible and yield the same ultimate results, this investigation dealt primarily with what appeared to be the simplest method. Many of the above methods were investigated and have been used to advantage, but studies indicated that a fairly simple approach to the problem might be the use of conduction methods.

The first investigation was the use of a metal shoe in contact with the bulb wall. The metal shoe transferred heat from the bulb wall to a fin which is cooled by air. This combination of shoe and fin will be referred to as a "sail."

Fig. 4 shows the light output curves for an F96T12 high output lamp operated at various currents with and without a "sail," in still air at an

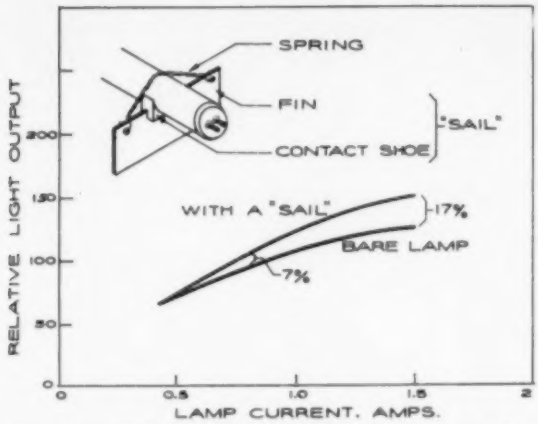

Figure 4. Relative light output versus current of a 96T12 lamp operated with and without "sails".

ambient temperature of 77F. At each current, the "sail" design was such as to result in approximately maximum light output.

For example, an F96T12 high output lamp operating at 800 ma in 77F still air showed an increase of 6 per cent when a "sail" was used to cool a point on the bulb wall.

The above data indicate that when fluorescent lamps are operating at higher than optimum mercury pressure, due to high loadings or high ambient temperature, the "sails" are effective in obtaining higher light output. Therefore, the next phase was to evaluate "sail" sizes, geometry and materials. Specifications for "sails" are hard to give in detail because of the wide variation encountered in service conditions of ambient temperature and draft conditions. However, some results are applicable.

"Sail" Material

Copper has the advantage of having the best heat conductivity of common metals; aluminum is next, having about half the conductivity of copper, but being much lower in cost. Steel was also tried. but since its thermal conductivity is only one-fourth that of aluminum, it gave poorer results. Fins and shoes of aluminum or copper were both good and gave about the same performance.

Coatings on the surface of the fin were also varied, from a polished chrome plate intended to reflect radiation that might raise the fin temperature, to a black painted fin intended to increase the efficiency of radiation. Little difference was found in these, and there seems to be little preference in surface coatings.

Fin Size

The fins must be large enough to transfer heat absorbed from the contact shoe to the surrounding air with only a small temperature rise above ambient. Since this heat is transferred mainly by convection, the size of the fin is dependent upon possible air circulation around it. In open air for a highly-loaded T12 lamp, 1/32-inch thick fins with areas from 3 to 16 square inches were tested, and a minimum area of about 7 square inches is recommended, althought here may be some use for even smaller areas, especially if there is good air circulation around the fin.

Shoe Size

As the shoe must transfer heat from the bulb wall to the fin with little temperature differential, it must be of reasonably large cross section and must fit the contour of the bulb. There must be little temperature differential between all parts of the "sail" and the bulb. Furthermore, the area of the shoe must be large enough to allow mercury to condense in a thin layer, but not so large as to obstruct undue light.

Shoes selected for test had areas contacting the lamp ¼-inch wide and 1-inch long, also ½-inch wide and 1-inch long, and were ¼-inch thick. A shoe ¼-inch wide was satisfactory, but had a tendency to tilt on the lamp. A shoe ½-inch wide fitted against the bulb wall more firmly. Shoes wider than ½-inch introduced the possibility of poor contact due to bulb variations.

"Sails" (Shoe and Fin Combination)

Some examples of the types of "sails" tested are shown in Fig. 5. It is essential that the shoes seat firmly, fit the contour of the bulb and be held securely in place by spring tension. There is no reason why these "sails" cannot be designed to be unobtrusive and an integral part of the luminaire.

"Sail" Position on Lamp

In applications where open top luminaires are so mounted that there is air circulation around them, it may be desirable to mount the "sails" on top of the lamp. Therefore, some tests were conducted

Figure 5. Some of the "sail" types tested.

with "sails" mounted in this manner, indicating that they were effective in controlling mercury pressure. However, as the air is usually slightly warmer at the top of the luminaire, there is some advantage in placing the "sail" below the lamp.

Stabilization of Lamps with Cooling Devices

When cooling devices are first used on a fluorescent lamp, an initial stabilization time will be required for the excess mercury to migrate to the cold spot or shoe area. This initial stabilization time, which may take many hours, depends on lamp loading, temperature differential within the lamp, and initial mercury distribution and quantity. Most lamps when operated with "sails" will stabilize initially in approximately 24 hours. The restabilization time after the lamp has been turned off over night occurs fairly rapidly—in approximately 30 minutes or less.

Effectiveness of "Sail" Design

To check the effectiveness of a "sail" design the luminaire should be operated until reasonably stable from a temperature standpoint, then a light output reading obtained without the use of the "sails." The "sails" should then be put in place and the luminaire operated under comparable conditions until the lamps are stabilized (approximately 24 hours as mentioned previously.) After this stabilization period, a light output reading can be obtained, and compared with the reading without the "sail" in place.

To determine if a "sail" is functioning properly, the fin can be cooled by a blower, ice, or any other means. If the "sail" is effectively reducing mercury pressure, the light output will rise as the fin is cooled, go through a peak, then drop off rapidly.

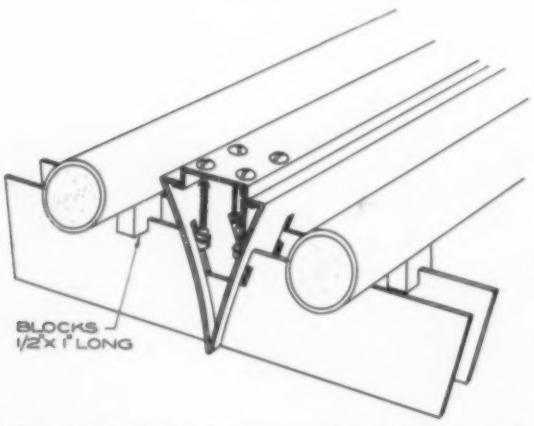

Figure 6. Spring-loaded louvers with cooling contacts; section through center of luminaire. The rest of the louvers are normal.

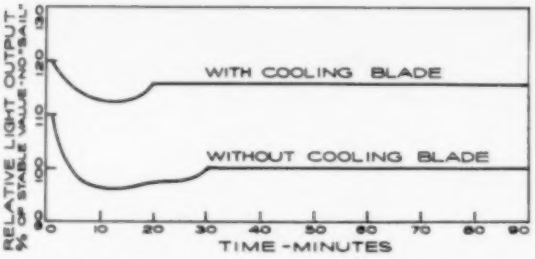

Figure 7. Effect of cooling louver blade on light output 96T12 high output lamp at 1.5 amperes, 80F room temperature.

The peak value of light recorded is the maximum which could be obtained with any "sail" or cooling condition. This will also determine whether a "sail" design can be improved. For example, it may be desirable to reduce the size of the fin to give peak light output. The result would be operation at a slightly higher mercury pressure. This would compensate for unusual draft conditions or slight reductions in ambient temperature which could result in overcooling and fall off in light output.

Application of "Sails" to Luminaire Design

From the above studies on external cooling devices, there were indications that "sails" could most practically be incorporated into new luminaire designs. Two spring-loaded louvers were designed to act as "sails." These were incorporated into a typical suspended luminaire of open-top design using 96T12 high output fluorescent lamps (see Fig. 6). The "sails" took the place of two of the louver blades.

Since the effect of mercury control is easier to evaluate at high loadings, the 96T12 high output lamps were operated at 1.5 amperes, almost double their normal current. Tests were conducted on this luminaire at normal room temperature and draft conditions. Fig. 7 shows the restabilization for the lamps in the luminaire, with and without the cooling device. The curves show 17 per cent gain in light output when the cooling louvers are in operation. When the same luminaire was operated in a higher ambient of 100F, the light output gain was approximately 25 per cent (see Fig. 8). Tests were also conducted at normal current.

Fig. 9 shows a view of an office lighted with 96T12 high output lamps used in open top luminaires in which "sails" have been incorporated. Data were taken over a two-week period with the lamps operating both with and without "sails," in a room temperature of approximately 80F. An average gain of eight per cent in output was obtained.

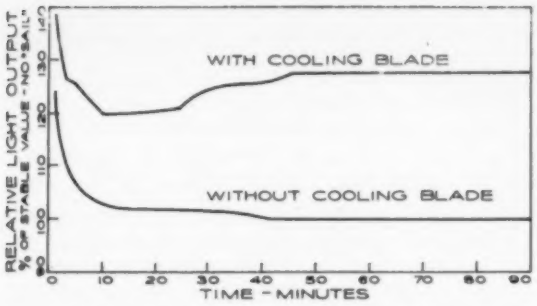

Figure 8. Effect of cooling louver blade on light output 96T12 high output lamp at 1.5 amperes, 100F room temperature.

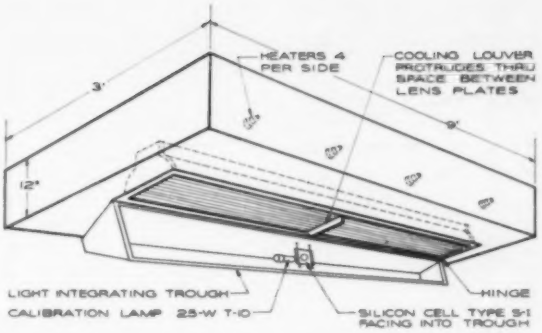

Figure 10. 96T12 two-lamp enclosed troffer mounted in simulated ceiling cavity.

Recessed Luminaires

The gain in light output shown for a suspended open-type luminaire indicated it would be desirable to explore a recessed type where the heat around the lamps would be more confined. Obviously, there are so many variables in conditions of installation for recessed luminaires that it would be extremely difficult to determine what might be considered a typical cavity temperature. The main interest is the air temperature in the vicinty of the lamps. This is also difficult to predict.

The purpose of this test is to indicate direction rather than devote the time required to test a number of luminaire types in various cavity sizes, materials, etc. Therefore, a completely enclosed troffer was selected for test purposes. This luminaire was mounted in a simulated ceiling cavity as shown in Fig. 10. The box or cavity was designed and equipped with heating elements so that the temperature could be varied over a range. The air temperature around the lamps was then recorded by means of thermocouples.

Two 96T12 slimline lamps were used in an enclosed recessed troffer. The cooling "sail" designed for this unit is shown in Fig. 11. It was located at the junction of two enclosing glass covers. The "sail" was so designed that the cooling shoes contacted the lamp and held the fins in place. (This was satisfactory for test purposes; however, it is not suggested as a means of design of an actual luminaire.) The fins projected approximately 1½ inches below the glass covers.

The room ambient was maintained at 80F and the temperatures within the simulated cavity were controlled from 90-140F. For comparison purposes, light output and air temperature in the vicinity of the lamps were recorded with and without the "sail" in place. These results are given in Fig. 12.

Figure 9. View of office lighted with 96T12 high output lamps in open top luminaires equipped with "sails".

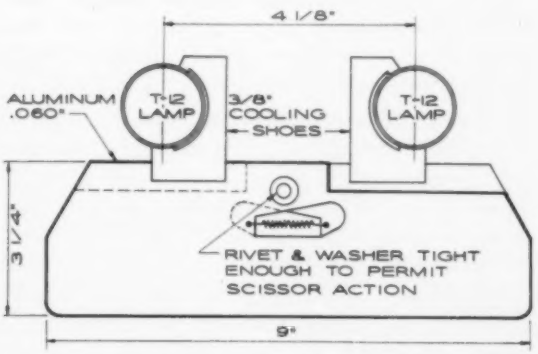

Figure 11. Design of cooling "sail" used in enclosed troffer test. (Notes: Two blades—one for right lamp, one for left lamp. Spring action pushes cooling shoes outward against lamps.)

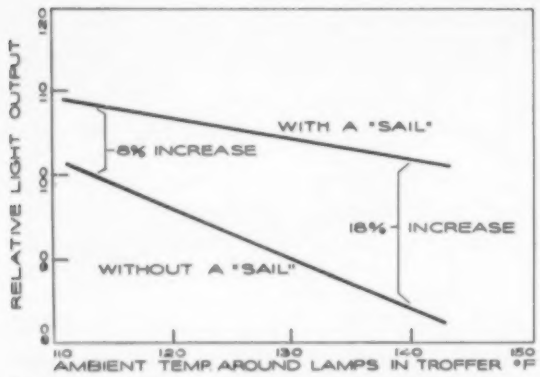

Figure 12. Relative light output versus ambient temperature around two 96T12 slimline lamps operating with and without a "sail" in an enclosed troffer. (Series sequence ballast with primary voltage held constant.)

In this case the light output was increased over a range of 8-18 per cent.

Use of External Cooling Devices

It is not the intent of the authors to recommend the indiscriminate use of cooling devices on existing installations. Our major purpose is to present information so that such devices can be properly designed and incorporated into new luminaires to obtain higher light output where higher ambient temperatures around the lamps prevail. On the other hand, indiscriminate use of external cooling devices such as those described might result in the following unfavorable operating conditions unless proper precautions are taken.

Lamp Breakage

Lamp manufacturers have discouraged the practice of having anything touch the surface of any lamp while it is in operation. On fluorescent lamps, the major concern is the damaging of the glass surface. However, if the cooling device is built into the luminaire, care can be taken to prevent excessive pressure against the lamp, lamp contact with rough or sharp surfaces, or cooling shoes which snap against the lamp when it is put in place.

Low or Moderate Temperature Locations

The use of "sails" in low or moderate temperature locations could result in over-cooling of the lamp. This would, of course, be dependent on luminaire design and the wattage incorporated into it. It is therefore essential that the type of lamp, luminaire and surrounding ambients be considered for effective use of external cooling devices.

Ballast Temperatures

Since the use of an external cooling device may raise the lamp wattage, the ambient temperature in the lamp cavity could increase. It is therefore conceivable that ballast temperatures would be affected. This is another factor which requires consideration.

Summary

It has been shown that under some conditions of operation the mercury pressure in fluorescent lamps may be high enough to result in decreased light output. Simple low cost cooling devices can be designed into new luminaires to effectively reduce mercury pressure. For example, gains of 8-18 per cent were obtained in an enclosed recessed troffer for ambient temperatures around the lamps of 112-140F.

A cooling device can consist of an aluminum shoe and fin combination. The shoe should be approximately ½-inch wide by 1-inch long and ¼-inch thick, and the fin approximately 1/32-inch thick with a minimum area of 7 square inches.

The intention of this work is to point out some results from external cooling devices as a means of obtaining gains in light output for fluorescent lamps operated in the higher ambient temperatures. While the cooling devices are simple, the conditions of operation and installation as well as luminaire design must be taken into account in applying them.

Experience indicates considerable ingenuity and test work may be necessary before ariving at a new luminaire design for a particular condition of operation. However, the gains in many cases would make it worthwhile.

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DISCUSSION

GORDON C. HARVEY:* The work reported in this paper is commendable for several reasons. Possibly the most salient is the opportunity shown for fixture and lighting system design for improved efficiency. The data confirm the observation that some compact fixture designs incorporating the best components may have a smaller lumen output than a less compact fixture design using marginal components, such as ballasts of a lower light output rating.

The authors' advice against the indiscriminate use of sails is quite appropriate and might indicate that their use should be limited to specific installations where the ambient conditions warrant them.

Several possible methods of controlling the cold spot tem-

*General Electric Co., Ballast Dept., Danville, Ill.

perature are listed. For open and louvered types of fixtures, the sail method should be the simplest and least expensive; however, the other possibilities should not be overlooked. Sail cooling may be difficult to apply in enclosed flush-mounted or recessed fixtures, and it would seem that in these applications, cold spot control would show the greatest gains due to the usually higher lamp compartment ambient temperature. For these applications, air jets, fans, or cooling coils might be the best solution. An additional gain could be made using one of these methods in such a manner that they could be used to dissipate ballast heat as well as lamp heat, thereby increasing ballast life.

I have one question: To what extent, if any, would the normal photometric procedure (including time) need to be changed to make sure that the efficiency improvement is observed when the output of a fixture equipped with sails is to be measured?

C. L. AMICK:* While general information regarding the effect of ambient temperature on light output of fluorescent lamps has been published previously, this paper brings into sharper focus the need for the fixture designer to have much more knowledge on the subject. Certainly, higher current lamps and greater numbers of lamps per fixture will be a means of achieving the IES footcandle recommendations, and methods to obtain higher light output from lamps will be most welcome by the lighting industry.

For commercial application, the preference by specifiers for ceiling-mounted luminaires appears to be on the increase. If the room ambient is 75F, the temperature at the ceiling line will be around 80F. The temperature inside the fixture is even higher, probably up to 120F in a completely enclosed design. Fig. 2 of the paper shows that 430 ma T-12 lamps reach their maximum light output at ambients of approximately 70F, and 800 ma T-12 lamps around 60F. The output of such lamps inside ceiling-mounted fixtures will obviously be lower than optimum, and we applaud the efforts of Messrs. Underwood and Beck to cool a portion of the fluorescent lamp for higher light output.

Many of today's buildings use the ceiling cavity as part of the return air system, thus exhausting room air. In such cases, ceiling cavity air temperatures seldom exceed 90-100F. If sails or other means were used to conduct heat from the lamp to the troffer body above the ceiling line, would there be sufficient transfer to the cavity air to obtain the desired reduction in bulb-wall temperature? Such a plan, with contact surfaces on the top half of the lamp diameter, would avoid the appearance disadvantage of sails projecting through the enclosure as suggested in Fig. 10, and permit more simple relamping procedures.

Unfortunately, fixture designers have little real control over the product used in service. The situation of two bulb sizes of extra high output (1500 ma) lamps comes quickly to mind as an example of the luminaire manufacturer not knowing which of the two sizes of lamps is to be installed in those particular fixtures. While 96-inch TD-17 bulbs were not discussed in the paper, can the authors comment on the effect of sails on the light output of the grooved type of extra high output lamps?

M. E. KECK:** The paper discusses a method of external control of mercury pressure in fluorescent lamps using a heat sink which may be detached from the lamp. I believe that a logical conclusion which is omitted from the paper should be added, to the effect that the heat sink should be located at the point on the lamp where the coolest spot will normally exist. This would be at the middle of the lamp in those cases where the lamp manufacturer has made no effort to produce a cool spot at another location and would be the location on other lamps where the lamp manufacturer has designed the cool spot to exist.

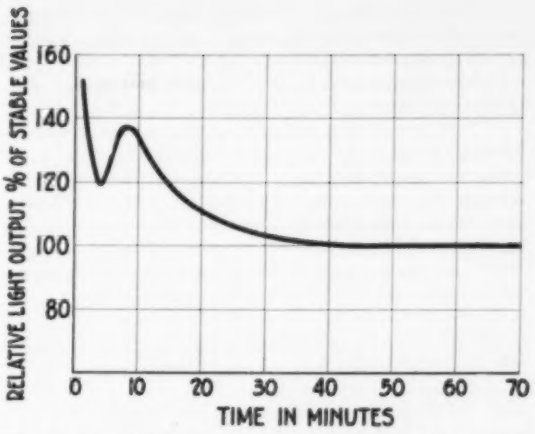

Figure A. Light output vs. time. Extra high output lamp in enclosed street light.

Much of the data in this paper have been taken with the use of 96T12 lamps operated at approximately double the rated current. The results of such tests serve only to show that improvement can be made and are not relative in terms of the amount of improvement for lamps operating at their rated current. I do not feel that it is proper to consider such data applicable to the extra high output type lamp since in such a lamp, a specifically designed cool chamber is located at the end of the lamp and the authors have placed their sails at the center of a totally different lamp.

The shape of the curves in Figs. 7 and 8 is quite unbelievable. There must have been some condition not readily apparent and I must ask for a fuller explanation, particularly as regards the exact status of the lamp and luminaire at the time, zero, on these curves. Fig. A of this discussion indicates for a two-lamp enclosed fluorescent floodlamp, a light output *vs* time curve taken in our own laboratories which we have found to be typical of high output lamps operating under relatively high ambient temperature conditions. As you can see, the light output starts high, drops immediately, rises to a peak, and approaches stability on a downward slope of the curve.

In the authors' curves, stability is approached from the opposite direction. It is my opinion that stability is approached from lower light levels only in those cases where the lamp is operating with its cool spot below or equal to its optimum temperature. I also would like to quote from another paper,[1] by Messrs. Herrick and Wenner, who describe but do not picture this same kind of curve. Their description is as follows:

"Turn the luminaire on. Watch the light indication carefully. It should rise to a maximum value and then fall off to the value read in Step 4 above. Read the maximum value. The fall off process may take another half hour or more depending upon the bulk of the luminaire."

This description fits quite well my curve of Fig. A and does not fit at all the time current curves in Messrs. Underwood and Beck's paper.

In summary, this paper leaves me with several questions:

*Day-Brite Lighting Inc., St. Louis, Mo.
**Westinghouse Electric Corp., Outdoor Lighting, Cleveland, Ohio.

1. Have the authors considered the necessity of changing the sail contact location depending upon the type of lamp to be used in the luminaire?

2. Are sails considered necessary with the control mechanism employed in the TD-17 lamp?

3. Does the statement relative to lamp breakage indicate that the authors feel that smooth surface T12 lamps can be contacted by luminaire metal surfaces and if so, the luminaire designer must immediately ask for some specifications as to limits so that he may know when the lamp manufacturer will and will not guarantee this product.

4. I assume the omission of any discussion of sails for TD-17 lamps is deliberate and may I ask why?

1. Herrick, P. R. and Wenner, R. E.: "Measuring F-Lamp Characteristics for the Outdoor Environment," ILLUMINATING ENGINEERING, Vol. LIV, No. 11, p. 686 (November, 1959).

B. F. JONES:* Drop in light output due to temperature rise has been a problem of fluorescent lamps for years. In the past few years the problem has become much more acute, since the demand has been for shallow, ceiling-mounted or recessed fixtures in which it is very difficult to prevent high ambient temperatures. The authors deserve commendation for examining a relatively simple method of preserving the light output from the lamps when such operation is necessary.

The use of sails or other lamp contact devices in fixtures reminds me a great deal of the use of radiators to help transfer heat from a ballast to the air and fixture housing. I feel that such use is an admission of poor design, by either the ballast or the fixture manufacturer, and am inclined to apply the same reasoning to the use of such devices to obtain heat transfer from lamps. Can't lamps be designed for high ambients?

The NEMA subcommittee on lamp standardization has been advocating a slightly shorter 40-watt rapid start lamp for use in modular recessed fixtures. It would seem that this might be combined with design of a lamp to operate efficiently at somewhat higher temperatures, since the primary use of this lamp would be in just such applications.

Proper operating conditions should if possible be attained without resort to external devices, for several reasons. Attachment of extra parts may be difficult and adds to the expense. They are also prone to get out of adjustment, or be left off by maintenance personnel when lamps are replaced. Placing the sails below the lamps, while resulting in the most efficient operation, also creates the most problems of obtaining proper contact while allowing ease of lamp maintenance in the types of fixture where the concept is most valuable (ceiling mounted and recessed). It also blocks the most light.

Sail contact on top of the lamp is easier to arrange, and more permanent in its attachment. However, it is not as effective in dissipating heat. The chief result in this case would be to transfer the heat to the fixture housing, which generally has other heat sources contributing, and lengthens the dissipation path.

For cases where these objections are overridden by the benefits, such dissipators should be very useful. I am thinking particularly of 800- and 1500-ma lamps used in surface-mounted and recessed applications. I am in doubt, though, as to how much increase in output might be obtained from 1500-ma lamps, which already have cool "pockets" built in. The authors' investigations at 1500 ma were made with 800-ma lamps operated overcurrent, which do not have the benefit of the cooling chambers built into 1500-ma lamps by all three major manufacturers. The gains of 17 per cent and 26 per cent shown in Figs. 4, 7 and 8, therefore, are subject to question unless verified by tests on lamps designed for this current.

One more point requires comment. The use of an external cooling device will, if it is effective, raise the wattage delivered to the lamp. Since the ballast is presumably designed to deliver rated wattage to the lamps at or near their maximum-output ambient (about 77F), there should be no problem of ballast overheating due to the effect of the sails. If there is, the design of either the ballast or the fixture is faulty. The sails should not be blamed. This does, however, pose a problem for Underwriters' Labs, since a fixture tested without sails which barely passed the 90F limitation could well overheat when sails are used. Might use of these accessories invalidate the fixture UL label?

JOHN J. NEIDHART:* This very enlightening and useful paper opens new avenues for improving the performance of luminaires equipped with today's more highly-loaded fluorescent lamps. Such improvements are necessary if we are to use these sources to best advantage. However, we must recognize that these new roads are not yet well-paved or even well-marked.

The use of sails in louvered equipment such as illustrated by Fig. 9 is particularly intriguing, and the reported eight per cent gain in light output is very significant. We are beginning to see 1500-ma lamps used in similar equipment, and the value of sails in such equipment should be even more striking. The equipment shown in Fig. 9 happens to have a one-piece, formed steel louver, so I assume that the sails in this instance are the painted steel louver blades to which the shoes are attached even though the authors state in another part of the paper that steel gave poorer results as a sail since its thermal conductivity is only one-quarter that of aluminum. Do the authors consider that the one-piece construction of the louver offsets this lower conductivity by providing a good conduction path permitting the entire louver assembly to help materially the louver blades to which the shoes were attached? The excellent results seem to indicate that this may have happened, and I wonder whether the authors have any comparable data for a multi-piece louver assembly.

The authors mention the use of sails initially to stabilize lamps in 24 hours. We have found sails to be very useful in our photometric laboratory as a means of reducing the stabilization time for 1500-ma lamps. Stabilization time for these lamps would normally be two and a half days, but by using sails with a fan cooling them, the lamps are stabilized overnight. The lamp stability thus attained has been very effective in enabling us to obtain consistent data. In such laboratory work the sails are removed, of course, after stability has been obtained and before the tests are conducted.

We are grateful to the authors for the information provided in this paper, and we hope that it will be used wisely. Improper use or design of cooling devices could result in poorer performance under many application conditions. Care must also be exercised in the photometric testing and reporting of luminaires equipped with cooling devices. I am sure that these problems will be recognized and that we will see considerable, intelligent use of such devices.

P. J. UNDERWOOD and C. E. BECK:** Replying to the discussers, we would say:

*Smoot-Holman Co., Inglewood, Calif.

*The Miller Co., Meriden, Conn.

**Authors.

Mr. Harvey—In regard to the question on photometric procedure, first, normal photometric procedure should be followed for the luminaire with the sails in place in the fixture but the cooling shoes not in contact with the lamps. When this is completed, the luminaire should be held in the horizontal position and a light output reading taken after temperature equilibrium is reached. Then the cooling shoes should be adjusted to contact the lamp, and the lamp allowed to stabilize by burning approximately 24 hours as described in the paper. Next, another light output reading should be taken and compared with the reading without sails to give a ratio of improvement which can be applied to all the normal photometric values.

Mr. Amick—If a troffer is cooled by air at 90F, our measurements in the simulated ceiling cavity with still air show that the reflector temperature rose about 5 to 10F with 96T12 slimline lamps in both open and enclosed troffers. If the bulb wall temperature is to be maintained at 100F for maximum light output, it is necessary to have a very good design of thermal system to take the heat from the spot on the bulb to the troffer wall with little temperature rise. Most good designs would still have a temperature rise of 5 to 10F. Thus, we are on the borderline of being able to obtain the exact temperature for maximum light output. However, we still feel that some gains could be expected. If the sails could extend through the troffer into the moving air above the fixture or into the cooler air below the fixture, greater gains might be obtained.

As regards the use of sails on grooved type extra high output lamps, these lamps are designed to give maximum light at close to the normal test conditions of 77F in still air. If the ambient temperature around these lamps is higher than normal, they will be down in light output and sails should be effective in raising their light output.

Mr. Keck—While there is an advantage in using the sails on the coolest point of the bulb wall, they will still be effective at any point provided they are designed to reduce the bulb wall temperature to its proper value. The advantage of using a sail where the cool spot normally exists is that this point is cooler and less heat must be transferred from this spot to cool it to a given bulb wall temperature. A sail at the cool point can be smaller than a sail used elsewhere on the lamp.

In regard to the question on the light output curves taken as lamps stabilize, the mercury pressure goes from a high value to a low one as the excess mercury transfers from a hot section of the bulb to a cool one. This means the lamp voltage, wattage, and light output will rise. This is shown in Figs. 7 and 8 as the lamps stabilize with a sail. The shape of the curve is not new. It is also shown in Gungle, et al, "Operating Parameters of High Output Fluorescent Lamps,"[1] in Fig 4 of their paper. These curves are similar to the ones shown in our paper.

Mr. Keck refers to a procedure given by Herrick and Wenner in their paper,[2] as to the effect of noting the peak output, and then reading the stable value after light output has fallen off. The curves shown in Figs. 7 and 8 and Mr. Keck's curve do not show the peak which is referred to by Gungle or by Herrick and Wenner. This peak value was obtained even before the first readings on these curves were plotted. The usual shape of this curve is as shown in Fig. 7 of the Barr-Karash paper entitled, "Design Of High Output Fluorescent Lamps."[3] Here light output rose to a peak value in just one minute then fell off until it reached a stable value, since this lamp has no built-in mercury pressure control. In more highly loaded lamps, this peak occurs very rapidly and for our purposes, it was not necessary to record it.

In regard to Mr. Keck's curve, it is true that light output will continue to drop after the cold spot exceeds 40C as shown in his curve for an enclosed luminaire, and also in our Fig. 12. In Figs. 7 and 8, the sail temperature did not rise appreciably as the luminaire warmed up.

In regard to the comment on lamp breakage, the authors feel that if proper precautions are taken, lamps could be contacted by a cooling device without any undue difficulty. As to the limits for design specifications, there are not sufficient data and experience to determine what the limits should be. Some suggestions were made in the paper. However, it is obvious that designs will vary depending on the type of fixture and/or application and it would seem that any question of lamp guarantees should come from individual lamp manufacturers.

In indoor applications today non-circular cross-section lamps are in most cases operating at or near peak efficiency by virtue of the mercury control feature which is built into the lamp. However, non-circular or other types of lamps with built-in mercury control, when operated in ambient temperatures higher than that for which they were designed, could still show improvement by applying the sail principle.

Mr. Jones—In regard to his question on lamp design, lamps are normally designed to furnish maximum light output close to 77F in still air conditions. If these lamps are used in higher ambients, light output will be down and external means can be used to restore it. It is true some attempts can be made to design special lamps for high ambients but then these lamps would be low in light output at normal ambients. Proper application of such lamps might be very hard to control. It must be remembered that a lamp is designed for optimum output at only one temperature.

As regards his comment on the use of external cooling devices, we believe many of his objections will be overcome if the sails are properly incorporated and become an integral part of new luminaire designs.

The exploration of sails on lamps at 1.5 amperes was included to show that sails are effective in controlling mercury pressure and that high current lamps need some form of mercury pressure control. The purpose of the paper is to determine the effect of external mercury pressure control for higher temperatures regardless of lamp type.

The authors also believe that the luminaire would probably have to be checked by Underwriters with sails in place if they are to be used in operation.

Mr. Niedhart—We have no specific data on various types of louver assemblies; however, as he has indicated, sail design is not just a matter of material, but also of construction, particularly the manner employed for making thermal joints between different parts of the sail. While louver assemblies have good mechanical joints, these may not be good thermal joints. For this reason, it is difficult to theorize whether one-piece construction would have an advantage over multi-piece louver construction. The only way to obtain such information would be by actual tests.

The results reported in our paper in Fig. 9 are due to the large louver area enabling the steel fin to give good results.

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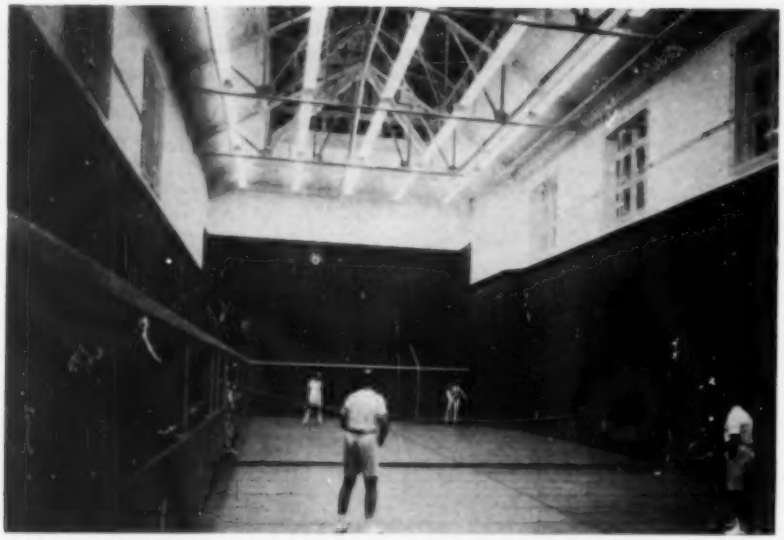

INSTALLATION AT THE RACQUET CLUB OF PHILADELPHIA, PHILADELPHIA, PA.

Lighting for Court Tennis

LIGHTING OBJECTIVE: To provide a high level of general illumination in the playing area for court tennis.

GENERAL INFORMATION: Court tennis is the original game from which lawn tennis, squash, squash racquets, badminton and handball, among others, evolved. The location shown above measures 38 feet by 108 feet. The ceiling height is approximately 40 feet. Colors and reflectances of the major surfaces are: ceiling and upper side walls, white (60% RF); lower side walls, slate gray (10% RF) for contrast between ball and wall; and floor, concrete (15% RF).

INSTALLATION: Sixty Ender-Monarch Corp. catalog No. 270-2-96PG fluorescent luminaires are suspended 30 feet above the floor in 5 continuous rows on 7-foot centers. Each luminaire is equipped with extra heavy protective louvers and two 96-inch TD-17 cool white fluorescent lamps.

After 500 hours' operation the average illumination at the net was 100 footcandles. The average in the rear court was 75 footcandles. Brightnesses were:

luminaire at 45°	1000 fL	end wall, upper	40 fL
floor	8 fL	lower	2 fL

Architect: W. L. Van Alen; Carrol, Grisdale and Van Alen. Consulting Engineers: A. Ernest D'Ambly and Stewart A. Jellett. Electrical Contractor: Harry F. Ortlip Co.

Lighting data submitted by P. R. Holmes, District Engineer, General Electric Co., Large Lamp Department, Philadelphia, Pa.

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LIGHTING NEWS

"Diabolo" Approved as New Name for East Bay Section

At the November 19 meeting of Council in New York City, approval was given for a change in name from "East Bay" to "Diabolo" for the Society's newest (No. 89) local group, with headquarters in Oakland, Calif. The new name is after Mt. Diabolo, Calif., a prominent landmark and geographic center of the area covered by the Section.

Charter for the Section was approved at the September 11 meeting of Council in San Francisco; its territory composed of counties formerly part of Golden Gate Section. Officers of the Diabolo Section include: Grant N. Radford, Pacific Gas & Electric Co., Oakland, Chairman; Leonard Komor, Sylvania Electric Products, Burlingame, Vice-Chairman; S. W. Brown, Weld-Rite Co., Oakland, Secretary, and Claude E. Parke, Pacific Gas & Electric Co., Richmond, Treasurer. Present membership is 89.

Petition for change in name was presented to Council by James R. Chambers, Vice-President of the Society and Chairman of the Regional Activities Committee, at the request of the membership of the Section.

The Diabolo Section is the second in IES history to organize, initially, as a section. (Minimum membership requirement for section status is 50.) The New Jersey Section, formed in October 1958, was the first local group to become a section immediately.

CHARTER NIGHT for Diabolo Section (formerly, East Bay—see story this page) was November 12 at Hotel Claremont, Berkeley, Calif. South Pacific Coast RVP, James E. Barnes (center), presented charter to Diabolo Chairman Grant W. Radford (left). Chairman Walter Bayha (right) represented his sponsoring Golden Gate Section at the celebration. Headquarters of Diabolo Section (IES No. 89) are in Oakland, Calif.

Chicago Lighting Exposition Planned for May 1961

First all-inclusive lighting exposition to be held in the Chicago area has been scheduled for May 1-3, 1961. The exposition will be held in conjunction with the Chicago Electrical Industry Trade Show, a biennial event sponsored by the Electric Association of Chicago. Site of the exposition and show will be the Lake Front Exposition Hall, now under construction.

Decision to conduct a lighting exposition was made by the Board of Directors of the Electric Association under President George Bard, Kelso-Burnett Electric Co. Exposition plans have the full support of the newly-organized policy committee of the Commercial-Industrial Lighting Industry, headed by Ole Hill, Jr., Commonwealth Edison Co. Mr. Hill is president of the Chicago Lighting Institute and a board member of the Electric Association.

All aspects of commercial, industrial, residential and outdoor lighting are included in the exposition plans. Response of the industry to the decision to hold the exposition indicates that the lighting exposition will be an important part of the Chicago Electrical Industry Trade Show. Hopes are that it will exceed in scope any exhibition of commercial and industrial lighting ever attempted in the United States.

Michigan Section Organizes Speakers' Bureau

Furthering the Society's goal of "IES to the Public," as emphasized strongly by Past-President George J. Taylor in his Presidential Report at the National Technical Conference in San Francisco, last September, the Michigan Section has organized a Speakers' Bureau as part of their lighting education program.

Aim of the Bureau is to present programs on any phase of current lighting practice to interested business and civic groups in the greater Detroit area. Speakers are recruited on a voluntary basis from the Section membership.

Professor Edward L. Fairchild, Wayne State University, is chairman of the Speakers' Committee, with Harry R. Rob-

(Continued on page 7A)

Here and There With IES Members

Representatives from East Central Region's six sections and chapters met in Hagerstown, Md., with Regional Vice President Carman D. Miller (seated at left under portrait) and IES Managaging Director A. D. Hinckley (to Mr. Miller's right) for discussion of common problems, regional and section/chapter activities.

New Jersey Section program chairman, Harvey L. Sykes (right), points to one of the exterior lighting fixtures at Garden State Plaza, Paramus, N. J., during recent Section tour of the shopping center. Looking on, left to right, foreground are J. F. MacDougall, Section Chairman; Fred Thurkauf, Jr., Public Service Electric & Gas Co., and B. F. Thomas, Jr., director of the electrical division, Abbott, Merkt & Co. About 100 members of the New Jersey Section toured the Plaza to inspect the lighting. Tour followed a dinner meeting at which Messrs. Thurkauf and Thomas discussed the Plaza's exterior illumination system.

Woman of Distinction Award to Mary L. Wallace, residential lighting engineer with Texas Power and Light Co., Dallas, was presented by Business and Professional Women's Clubs at luncheon in observance of National Business Women's Week. Miss Wallace, who won first place honors in the Southwestern Region's 1959 MMILJ competition, was one of 11 Dallas women honored at the luncheon.

Architectural lighting and light as an element of design were phases of the art considered at recent Rocky Mountain Section meeting. Speakers, l. to r.: Henry Lowenstein, Bonfils Memorial Theatre; Tom McCurry, technical director of paint manufacturing firm; (Fred Leffler, moderator); Stan Morse, Denver architect. Fourth speaker at the meeting was industrial designer Charles Deaton.

(*Continued from page 5A*)

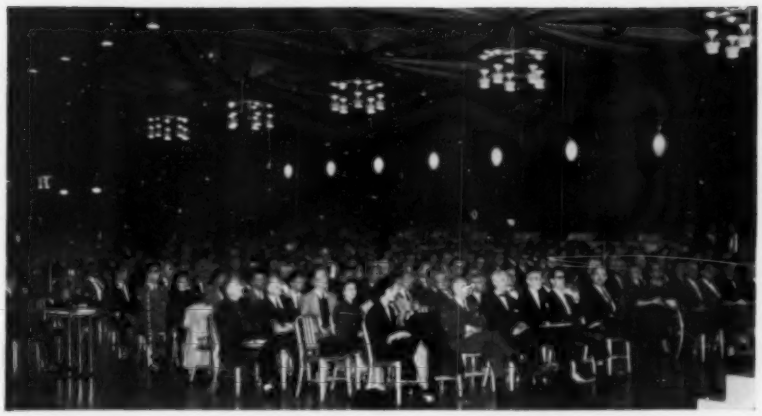
bins, General Electric Co., and James F. Finn, The Detroit Edison Co., serving as committee members. Topics offered by the Bureau include maintenance, illumination fundamentals, sources, electroluminescence, high frequency lighting, high voltage lighting for buildings and all phases of lighting application.

Case Institute to Enroll Women Undergraduates

Breaking an 80-year tradition, Case Institute of Technology, Cleveland, Ohio, has announced plans to accept applications from women students for admission beginning in the fall of 1960. The change in policy, as announced by Acting President Kent H. Smith, was made in response to the demonstrated national need for more graduates in engineering and science and the growing number of interested and qualified women high-school students.

Due to lack of dormitory space, only women candidates who can live at home or with relatives in the greater Cleveland vicinity will be accepted next fall. Beginning in 1961, however, qualified students from any area will be admitted, depending on available approved living accommodations in the Institute area.

Up to 1953, five undergraduate degrees had been awarded by Case to women students. Since that time, only one female student, a girl who came to the United States following the Hungarian Revolution, has been awarded a bachelor's degree from the Institute.



HUNDREDS of businessmen and merchants from the greater Cincinnati area, southwestern Ohio and northern Kentucky, attended "New Lighting Frontiers" forum to hear Dr. H. Richard Blackwell, IES Technical Director, C. L. Crouch, and Willard C. Brown discuss and demonstrate the new IES recommended levels of illumination. Forum was held, appropriately, in recently relighted Cincinnati Music Hall Ballroom, where versatile lighting system can accommodate anything from a meeting to a TV show (see story, November IE, page 671).

Blackwell, Crouch, Brown Speak At Cincinnati Lighting Forum

Ways in which better lighting can increase production and improve employee morale were vividly demonstrated to hundreds of businessmen and merchants from the greater Cincinnati, southwestern Ohio and northern Kentucky area at the two-day "New Lighting Frontiers" forum, held in the Cincinnati Music Hall Ballroom, October 27 and 28.

Theme of the meeting was the presentation of the new IES recommended footcandle levels for specific tasks in industry, commerce and offices. High lighting the program were a report by Dr. H. Richard Blackwell on his eight-year research program which provided the basis for the revised IES recommendations; a talk by C. L. Crouch, IES Technical Director, on "Bridging the Gap Between Research and Application" and a demonstration by Willard C. Brown, manager of lighting education, General Electric Co., Cleveland, on the application of higher levels of illumination.

The forum was divided into two sessions—commercial and office lighting on October 27, industrial lighting problems on October 28.

Co-sponsors of the successful forum were the Ohio Valley Section of IES, Cincinnati Gas & Electric Co., Large Lamp Department of General Electric Co. and Union Light, Heat and Power Co.

KENTUCKY Colonel Commissions conferred by Hon. Andrew J. Jolly (second from right), Judge of Campbell County Court, Newport, Ky., on (l. to r.) Willard C. Brown, Dr. H. Richard Blackwell and C. L. Crouch. Presentation was made at "New Lighting Frontiers" forum, held in Cincinnati, October 27-28.

Classical Theory on Color Perception Disputed

(The following is an excerpt from an article by Harold M. Schmeck, Jr. in The New York Times *of November 29, 1959.)*

The contention that color perception is more complex than the classical theory would indicate has been supported by a new mathematical study. The crux of the classical theory is that color results from a wavelength of light which acts upon the red, green and blue color receptors in the eye. An object appears colored in proportion to the mixture of reflected wavelengths. However, Dr. Michael Woolfson, British crystallography specialist, in

(*Continued on page 8A*)

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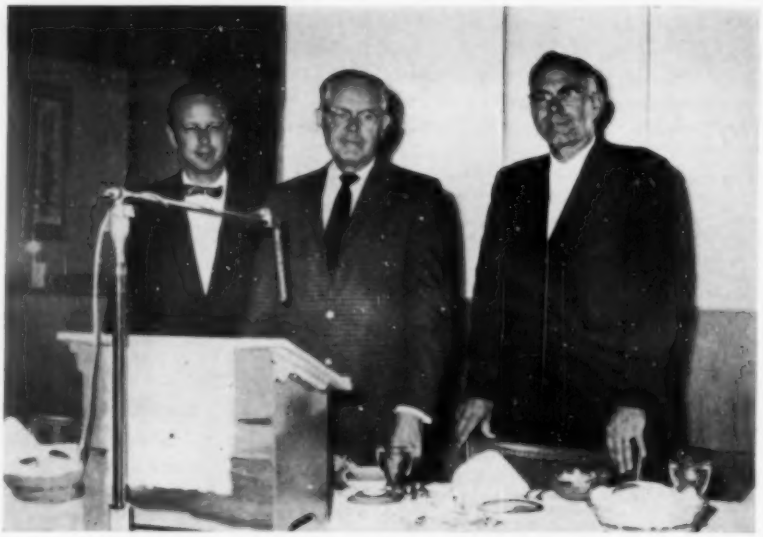
a report published in "The I.B.M. Journal of Research Development," asserts that object color is a result of the analyzation of incoming light from the object in relation to the light contained in the entire viewing area; thus, the perceived color is determined by the proportion of short wavelengths to long over a complex natural field of vision. Dr. Woolfson's report is a mathematical analysis of the experiments of Dr. Edwin H. Land of the Polaroid Corp., Cambridge, Mass., who has concluded that balance of wavelengths is the factor used by the eye for color perception.



FT. LAUDERDALE, Fla., Study Group's first technical meeting (on residential lighting) featured talk by Eugene W. Commery (center), IES Fellow and residential lighting expert. Shown here with Mr. Commery are Robert Mills (left), program chairman, and Walter C. Qualmann, study club chairman. Southeast Florida Section is sponsoring the study club.

Study Group Organized in Ft. Lauderdale, Fla.

Under the guidance and direction of the Southeast Florida Section of IES, a study group has been formed in Ft. Lauderdale, Fla. Organizational meeting, held October 1, was attended by 39 interested architects, engineers, electrical contractors and lighting representatives. Aims, purpose and organization of IES were explained to the group by Frank E. Yanaros, Chairman of the Southeast Florida Section.

A second meeting of the study club featured a talk by IES Fellow, Eugene W. Commery, on residential lighting. Mr. Commery, who retired a little over a year ago, had been director of residential lighting for General Electric Co., Nela Park, Cleveland.

Officers of the Ft. Lauderdale study club, Walter C. Qualmann, Chairman; T. C. Kendrick, Vice-Chairman; E. Y. Eaker, Secretary-Treasurer; A. F. Anderson, W. A. Furst, H. H. Hanson and Tom Marshall, Board of Managers, are hopeful that the club will meet the requirements for Chapter status during the 1960 IES year.

In addition to the club at Ft. Lauderdale, other groups which look to charters in the near future are already holding meetings in Alaska; Decatur, Ill.; El Paso, Texas; Eugene, Ore.; Gary, Ind.; Hawaii; Louisville, Ky.; Mobile, Ala., and Rockford, Ill. This burst of activity suggests that 1960 may be IES's most fruitful year in chapter organization.

Traffic Engineering Fellowships Offered by Yale University

Bureau of Highway Traffic of Yale University, New Haven, Conn., has announced the availability of fellowships for the 1960-1961 academic year. The fellowships, to be awarded to qualified graduate engineers who are citizens of the United States, cover a full academic year of graduate study, beginning in September 1960 and ending the following May.

Total value of each fellowship is $2200 —$800 for tuition and $1400 for a living stipend, disbursed at the rate of $175 per month for the eight months of the school year. These fellowships are available through grants to the Bureau from the Automotive Safety Foundation, Esso Safety Foundation, Insurance Institute for Highway Safety and The James S. Kemper Foundation.

Tuition scholarships are also offered

(Continued on page 10A)

A-777

EVER LOOK AT RELIGHTING THIS WAY?

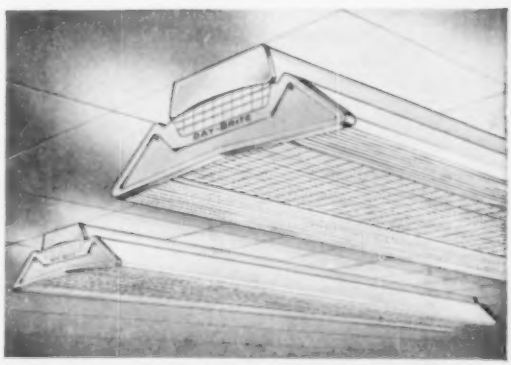
The unusual perspective shown above illustrates this point: To get the most from each square foot of *floor* space, make the most of *ceiling* space. And the hardest working ceilings are planned around Day-Brite "Full Comfort" lighting.

This is particularly true in the modernization of offices, plants and stores. Nearly always, the easiest and most effective way to increase productivity is by relighting with Day-Brite equipment. In the complete Day-Brite line, you'll find fixtures that solve problems caused by structural or budget limitations — fixtures delivering highest illumination efficiency without sacrificing appearance. To make sure *your* clients get the most from their ceilings, consult your Day-Brite representative. He's listed in the Yellow Pages.

DAY-BRITE

Day-Brite Lighting, Inc., St. Louis 15, Missouri and Santa Clara, California.

When you get down to "ceiling plans" call Day-Brite



DAY-BRITE'S NEW FAIRVIEW

For offices, stores and schools. 8 feet of Day-Brite quality and performance at half the price you'd expect to pay! Features the first full 8-foot prismatic enclosure. Low-brightness CLEARTEX® panel of X-5 plastic (guaranteed not to discolor for 5 years). Translucent sides for soft ceiling lighting. Designed for easy installation, speedy servicing.

"SPECIFYING Lighting Equipment" was subject for discussion by panel of experts at Southern California Section meeting. At the head table, in the usual order: Jerry Silvers, study club chairman; E. F. Miles, manufacturers' representative; Attorney D. T. Farrell, speaker at study club meeting; J. Roy Jones, secretary-treasurer; J. N. Robertson, electrical engineer; Benn Hartmann, section chairman, and J. S. Hamel, program chairman. Also participating in panel was architect Robert Field, Austin, Field & Frye.

Illumination Courses Offered by Philadelphia Section

The Philadelphia Section of IES is sponsoring, for the tenth consecutive year, two courses in illumination design to be held at the Engineers' Club of Philadelphia. Each course consists of ten weekly, two-and-a-half-hour sessions for which the tuition fee is $30. Illumination Design I, commencing on January 19, is a fundamentals course open to any person wishing basic training in lighting and will be conducted according to the following outline:

January 19—Light and Sight, A. S. Turner.
January 26—Light Standards Control and Measurements, A. S. Turner.
February 2—Light Sources, Part I (Incandescent and Mercury), R. R. Enghouser.
February 9—Light Sources, Part II (Fluorescent), R. R. Enghouser.
February 16—Calculations, G. T. Anderson.
February 23—Wiring Fundamentals and Lighting Economics, J. R. Rodisch.
March 1—Interior, Part I (Schools and Offices), P. F. Kyack.
March 8—Interior, Part II (Stores and Public Buildings), G. E. Shoemaker.
March 15—Interior, Part III (Industrial), A. V. Schafer.
March 22—Exterior Lighting, A. V. Schafer.

Illumination Design II, beginning on January 21, will be concerned with material of an advanced nature and therefore geared toward an audience with some background and experience in lighting. Sessions are planned as follows:

January 21—New Developments in Lamps and Auxiliaries, P. R. Holmes and W. Mitchell.
January 28—New Footcandle Levels, R. R. Enghouser.

(*Continued on page* 13A)

(*Continued from page* 8A)

by the Bureau to qualified municipal and state highway engineers who will also receive financial assistance from their employers during the tenure of their graduate study. This arrangement is considered a form of "in-service" training, by many employers.

The academic year of traffic engineering study consists of two semesters of classroom work, laboratory and individual research, field problems and seminars. Courses include traffic characteristics and measurements, traffic regulations and control devices, highway planning, highway location and geometric design, and highway administration and finance. Experts in traffic and related fields from all over the country participate in the program as guest lecturers.

Applications for admission and further information is available from Fred W. Hurd, Director, Bureau of Highway Traffic, Yale University, Stratheona Hall, New Haven, Conn. Closing date for filing applications is March 1, 1960. Candidates for fellowship and scholarship aid are not required to have previous experience in traffic engineering.

College-Industry Conference Studies Young Engineer

"The Young Professional Engineer—Our Mutual Responsibility" is the theme of the 12th annual College-Industry Conference sponsored by the Engineering School of Washington University, St. Louis, Mo. This year, on January 27-28, they will be host to the Relations with Industry Division of the American Society for Engineering Education at the meeting which unites leaders of industry and engineering education in the discussion of common problems. Plans for the upcoming conference include consideration of the responsibilities of the university, of the graduate, of industry and of professional societies in relation to the overall theme.

NEWLY-ELECTED officers of NEMA's Floodlighting Section, l. to r.: John A. McDougall, Revere Electric Mfg. Co., section representative on Lighting Equipment Division Board of Directors; John S. Haney, Crouse-Hinds Co., Section Chairman; S. R. Naysmith, Abolite Lighting Division, Jones Metal Products, alternate section representative on Board of Directors. Elections took place at 33rd Annual Convention of National Electric Manufacturers Association, held in Atlantic City, N. J., November 9-13, 1959.

How three companies use...

G-E Power Grooves for Sales Lighting. If your customers have products to display and sell, G-E Power Groove Lamps can play a vital role, as in the Fontius Shoe Stores, Denver, where 300 footcandles make shoe selection easy—and *fast!*

G-E Power Grooves for High Lighting Levels. Assembly Products, Inc., Chesterland, Ohio, gets 250 footcandles with mighty G-E Power Grooves— eliminated supplementary lighting, and saved *50¢ a square foot initial cost* at the same time!

General Electric Power Groove Lamps

... and get the lighting results they want

Conclusion:

Your customers get more and more light for their money, year after year, with G-E Lamps

What kind of lighting do <u>your</u> customers need? Light with sales appeal? A higher lighting level? Maybe the lowest cost of fluorescent light possible? Chances are General Electric Power Groove fluorescents are the lamps they should consider. Ask your G-E Large Lamp distributor for the whole story. General Electric Co., Large Lamp Dept. C-01, Nela Park, Cleveland 12, Ohio.

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G-E Power Grooves for Low Initial Cost. In Murray Hill, New Jersey, Bell Laboratories specified 100 footcandles in this engineering office and got it most economically with General Electric Power Groove Lamps.

ABOVE ALL:

LUSTREX PERMA TONE STYRENE LOUVERS!

Get all the usual advantages of styrene in lighting plus a resistance to yellowing up to 2 to 3 times that of regular styrene. How? Specify Lustrex perma tone styrene.

Specially developed to meet IES-NEMA-SPI joint specifications for ultra-violet light-stabilized styrene, this special Lustrex formulation exceeds these specifications and provides the large area of illumination, good diffusion, light weight for easy handling, good dimensional stability, and low cost that you have come to expect of styrene.

Perma tone offers unlimited translucencies in white and a complete color range. Proven in use by leading fixture manufacturers, molders, lighting engineers, architects, it has not been modified since 1956.

For free technical report on Lustrex perma tone styrene, including accelerated test results and other valuable data on styrene in lighting, write to Monsanto Chemical Co., Plastics Division, Room 704, Springfield 2, Mass.

LUSTREX Reg. U.S. Pat. Off.

MONSANTO innovator in **PLASTICS**

Louvers in London Public Utilities Building, London, Ontario by Wakefield Lighting Limited, London, Ont. Architect: Harold Hicks, London, Ontario; Electrical Contractor: J. V. McDonnell Electric Co., London, Ontario

Monsanto

(Continued from page 10A)

February 4—Architectural Aspects of Lighting, V. G. Kling.
February 11—Office and School Lighting, P. F. Kyack.
February 18—Stores and Public Buildings, G. E. Shoemaker.
February 25—Specialized Lighting Applications, G. E. Watt.
March 3—Luminaire Design, F. M. Pyle.
March 10—Industrial Lighting, A. V. Schafer.
March 17—Wiring for Lighting, A. L. Pentony.
March 24—Exterior Lighting, A. V. Schafer.

New Rules Announced for EEI Sales Promotion Contest

The Awards Committee of the Edison Electric Institute has announced new entry rules for the annual EEI Sales Promotion Awards competition. The awards, made for outstanding sales promotion campaigns conducted during the past year, are given in each of four areas —residential, farm, commercial and industrial. Three awards are made in each class, based on the number of meters served.

One important change in the competition rules allows 1959 entries to be based on individual phases of a company's over-all sales program in any of the four markets covered by the contest. Previously, an entry was required to cover over-all promotion.

Further information on the 1959 Sales Promotion Awards may be obtained by writing to Edison Electric Institute, 750 Third Ave., New York 17, N. Y.

Six New Member Companies Added to NEMA Roster

The National Electrical Manufacturers Association has announced the addition of six companies to its membership rolls. New members, their respective official representatives and NEMA section affiliations are:

Ripley Co., Inc., Middletown, Conn., F. A. Rudolph, Street Lighting Section;

Northeastern Engineering, Inc., Manchester, N. H., C. C. Hahn, Switchgear Section;

Texas Instruments, Inc., Attleboro, Mass., E. O. Vetter and E. F. Kurtz, Electrical Contacts, Industrial Control, Automatic Temperature Controls and Power Semiconductor Component Sections;

Gas Drying, Inc., Chatham, N. J., D. G. Hoke, Adsorption Section;

International Instruments, New Haven, Conn., L. E. Thomas, Electrical Indicating Instrument Section;

Hindle Transformer Co., Inc., Flemington, N. J., John C. Hindle, Specialty Transformer Section.

(Lighting News continued on page 14A)

SCHEDULED EVENTS

January 25-28, 1960—Plant Maintenance Show, Convention Hall, Philadelphia, Pa.

January 31-February 6, 1960—American Institute of Electrical Engineers, Winter General Meeting, New York, N. Y.

February 11, 1960—Council Meeting, Illuminating Engineering Society, New York, N. Y. Members are free to attend meetings of Council as guests.

February 11, 1960—Intermountain Electrical Association, Annual Conference, Hotel Utah, Salt Lake City, Utah.

February 22-25, 1960—National Rural Electric Cooperative Association (Annual Meeting), St. Louis, Mo.

February 25-26, 1960—Annual National Wiring Sales Conference, Warwick Hotel, Philadelphia, Pa.

March 6-9, 1960—Fifth Electrical Industries Show, New York City Coliseum, New York, N. Y.

March 10, 1960—Council Executive Committee Meeting, Illuminating Engineering Society, New York, N. Y.

March 23-26, 1960—Tenth Electrical Industry Show and Lighting Exposition, Shrine Exposition Hall, Los Angeles, Calif.

April 5-7, 1960—Building Research Institute, Spring Conferences, Statler-Hilton Hotel, New York, N. Y.

April 11-12, 1960—Inter-Society Color Council, Philadelphia Museum College of Art, Philadelphia, Pa.

April 20, 1960—Council Executive Committee Meeting, Illuminating Engineering Society, Memphis, Tenn.

April 21-22, 1960— South Central—Southeastern Regional Conference, IES, Hotel Peabody, Memphis, Tenn.

April 25-26, 1960—Southwestern Regional Conference, IES, Robert Driscoll Hotel, Corpus Christi, Texas.

April 28-29, 1960—Inter-Mountain Regional Conference, IES, Mountain Shadows Resort, Scottsdale, Ariz.

May 1-5, 1960—National Association of Electrical Distributors, Dallas, Texas.

May 4-5, 1960—South Pacific Coast Regional Conference, IES, Ambassador Hotel, Los Angeles, Calif.

May 9-10, 1960—Pacific Northwest Regional Conference, IES, Benjamin Franklin Hotel, Seattle, Wash.

May 10-12, 1960—American Institute of Electrical Engineers (Farm Electrification Conference), Sheraton-Fontenell Hotel, Omaha, Nebr.

May 12-13, 1960—Midwestern Regional Conference, IES, Sheraton Martin Hotel, Sioux City, Ia.

May 16-17, 1960—Great Lakes Regional Conference, IES, Hotel Carter, Cleveland, Ohio.

May 23-26, 1960—Design Engineering Show, Coliseum, New York, N. Y.

June 8-9, 1960—Northeastern Regional Conference, IES, Wentworth-by-the-Sea, Portsmouth, N. H.

June 13-14, 1960—Canadian Regional Conference, IES, Nova Scotian Hotel, Halifax, N. S.

June 16, 1960—Council Meeting, Illuminating Engineering Society, New York, N. Y. Members are free to attend meetings of Council as guests.

August 8-12, 1960—American Institute of Electrical Engineers, Pacific General Meeting, San Diego, Calif.

September 6-16, 1960—Production Engineering Show, Navy Pier, Chicago, Ill.

September 11-16, 1960—Illuminating Engineering Society, National Technical Conference, Penn-Sheraton Hotel, Pittsburgh, Pa.

September 28-30, 1960—Canadian Electrical Manufacturers Association, Sheraton-Brock Hotel, Niagara Falls, Ont.

October 5-14, 1960—American Institute of Electrical Engineers, Fall General Meeting, Chicago, Ill.

October 23-27, 1960—National Electrical Contractors Association, Las Vegas, Nevada.

November 14-18, 1960—National Electrical Manufacturers Association (Annual Meeting), Traymore Hotel, Atlantic City, N. J.

November 27-December 2, 1960—American Society of Mechanical Engineers, Annual Meeting, Statler-Hilton Hotel, New York, N. Y.

I.E.S. National Technical Conferences

1960 — September 11-16 — Penn Sheraton Hotel, Pittsburgh, Pennsylvania

1961 — September 24-29 — Chase Park Plaza Hotel, St. Louis, Missouri

1962 — September 9-14 — Statler-Hilton Hotel, Dallas, Texas

1963 — September 8-13 — Sheraton-Cadillac Hotel, Detroit, Michigan

(*Lighting News continued from page* 13A)

Sections Vie in Data Sheet Campaign

Some 89 Sections and Chapters of IES are currently in keen competition for "best with the most." Data Sheet submissions, that is. The campaign is the 1960 project of the Data Sheet Subcommittee (of Publications Committee) and is a new opportunity for personal and Sectional glory. Chairman of the project is C. L. Amick.

Compared to the benefits—in personal and company recognition of good lighting jobs, service to IES and to the lighting industry, to name a few—this is the easiest campaign ever announced. All Section and Chapter members need do is:

(1) Scout up, leaf through files, for any commercial or industrial lighting installation which meets current IES Recommended Practice for quantity and quality of illumination.

(2) Send to local Data Sheet Reporter (see his name below) or direct to C. L. Crouch at IES Headquarters:

(a) An 8- x 10-inch glossy photograph of the installation. Note: These must be taken without daylight, unless it is a daylighting installation which is measured and illustrated. No supplementary photographic lighting; no flash or floods.

(b) Name and address of the installation.

(c) Task performed (if not obvious).

(d) Footcandles (on task).

(e) Names and addresses of people to be contacted for additional data.

Scores will be kept on all Sections and Chapters, the quota being one Data Sheet per every 75 members within the Section. (See each Section's quota in the list below.)

Local Data Sheet Reporters in all the Sections and Chapters will be the central instigators in the campaign. To help your Section be *best* in this service (with plenty of publicity to prove it), send this man pictures and simple data on all of your good jobs.

Data Sheet Campaign

Section/Chapter	Data Sheet Quota	Data Sheet Reporter
Alabama Section	2	Donald Hallmark 4202 Oak St. Montgomery 5, Ala.
Alamo Section	1	Lon W. Travis Beretta, Greenslade & Assoc. Inc. 1927 N. St. Marys San Antonio, Texas.
Arizona Section	2	Harold Stead 3501 E. Fillmore Phoenix, Ariz.
Arkansas Chapter	1	Bryant Rucker Curtis H. Stout 400 Shall St. Little Rock, Ark.
Ark-La-Tex Chapter	1	J. G. Harriss, Jr. Paul O. Rottman, Consulting Engineer Room 211, Hunter Bldg. Shreveport, La.
Arrowhead Chapter	1	S. H. Mallory California Electric Power Co. 598 "F" St. San Bernardino, Calif.
Bluenose Chapter	1	W. J. Phillips 9 Crestview Drive Armdale, N. S.
British Columbia Section	2	H. Lindgaard 7010 Ontario St. Vancouver 15, B. C.
Buckeye Chapter	1	W. T. Smith 3460 Meadow Lane Grove City, Ohio.
Capital Section	2	B. K. Connor Potomac Electric Power Co. 10th & E Sts., N. W. Washington, D. C.
Central Florida Chapter	1	Richard A. Gale Gale Lighting 2301 Howard Ave. Orlando, Fla.
Central Illinois Chapter	1	Richard Randall 1110 Parkside Ave. Peoria, Ill.
Central Kansas Chapter	1	John K. Gore 1264 S. Minneapolis Wichita 16, Kans.
Central New York Section	2	Warren O. Benjamin 63 Wilson St. Corning, N. Y.
Central Oklahoma Chapter	1	R. L. Jackson Oklahoma Gas & Electric Co. P.O. Box 1498 Oklahoma City, Okla.
Chicago Section	6	M. E. McCreight 1120 Adams Winthrop, Ill.
Chinook Chapter	1	Y. H. Lefebvre 1612 21a St., N. W. Calgary, Alta. Holophane Co., Inc.
Cleveland Section	4	Arnold D. Federman 3437 Ormond Rd. Cleveland 18, Ohio.
Coastal Bend Chapter	1	C. D. Myers, Jr. Central Power & Light Co. Box 1369 Alice, Texas.
Coastal Empire Chapter	1	J. Arthur Maddox 409 E. 54 Lane Savannah, Ga.
Connecticut Section	3	R. J. Duquette General Electric Co. 185 Church New Haven, Conn.
Cornhusker Section	2	D. E. Wood Crescent Electric Supply Co. 308 Iowa St. Sioux City, Ia.

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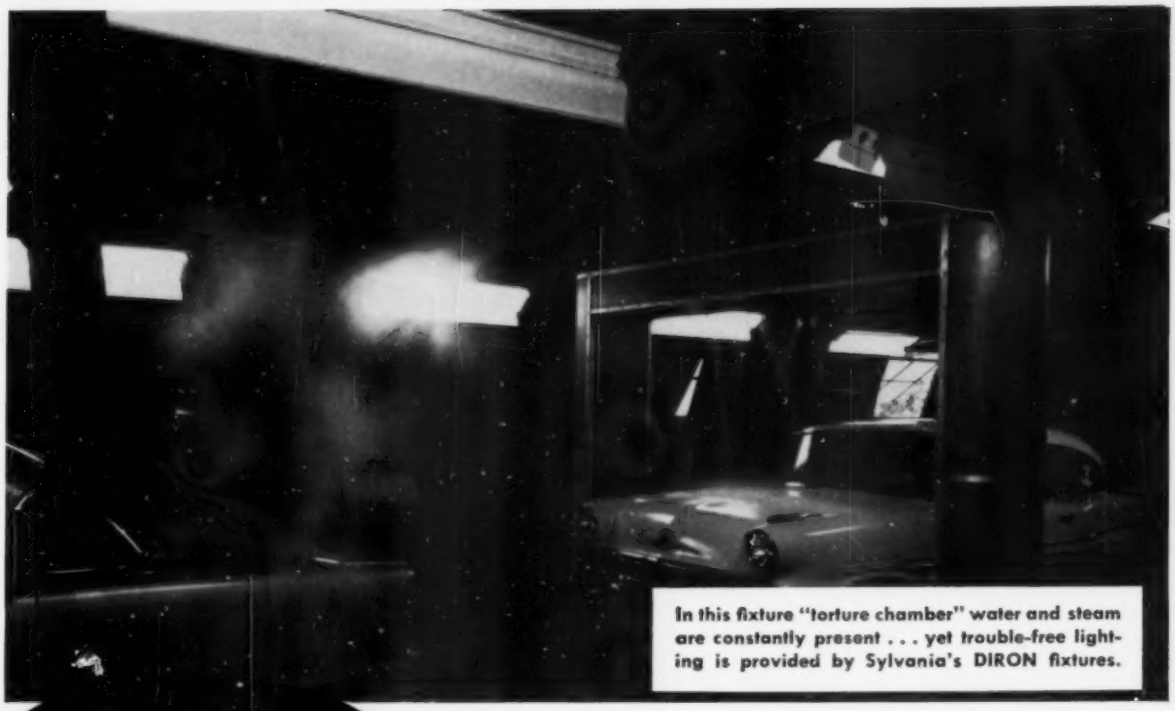

In this fixture "torture chamber" water and steam are constantly present . . . yet trouble-free lighting is provided by Sylvania's DIRON fixtures.

now... *True All-Porcelain Fixtures for Extreme Humidity Conditions*

Sylvania's New DIRON Fixtures

Here is a new, important advancement in fluorescent lighting fixtures . . . especially for textile mills, laundries, tanneries and other high humidity locations.

Selected Sylvania fixtures—both industrial and open-type—now have the new DIRON finish, a super-thin, all-porcelain process.

Every external part of these fixtures—*even the lampholder cases* for multi-lamp units—is protected against moisture by this exclusive DIRON process.

By this new method a tough, durable layer of porcelain is applied to *all* exposed surfaces of the fixtures. Yet the finish is so strong and pliable that knockouts can be removed without damaging the porcelain protection.

You'll find these fixtures both practical *and* economical. The new DIRON fixtures cost much less than conventional all-porcelain units. And the price is so close to that of standard industrial fixtures that you'll want to use DIRON units when there is any chance of a high humidity or corrosive atmosphere.

For full information on Sylvania DIRON fixtures, write to:

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A Division of SYLVANIA ELECTRIC PRODUCTS INC.
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GO MODERN WITH LIGHTING BY **SYLVANIA** GENERAL SYSTEM

Subsidiary of
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FLUORESCENT LIGHTING FIXTURES AND SYSTEMS • BEST FIXTURE VALUE IN EVERY PRICE RANGE

(*Continued from page* 14A)

Section/Chapter	Data Sheet Quota	Data Sheet Reporter
Diablo Section	1	Grant N. Radford Pacific Gas and Electric Co. 1625 Clay St. Oakland, Calif.
Eastern New York Section	1	Ralph A. Reed General Electric Co. 8 Elk St. Albany, N. Y.
Eastern Pennsylvania Section	2	C. D. Shirley Route #1 Emmanaus, Pa. AND J. B. Duffy 1600 Linden St. Scranton, Pa.
Edmonton Section	1	W. R. L. Carmichael 14232 95th Ave. Edmonton, Alta.
Florida Section	2	J. A. Pettus 4413 Estrella Tampa, Fla.
Forest City (London) Chapter	1	R. W. Frank 184 Pinewood Drive RR #4 London, Ont.
Georgia Section	2	T. W. Haslam Georgia Power Co. 75 Marietta St., N. W. Atlanta, Ga.
Golden Gate Section	4	Richard Grundy 330 Hazel Ave. San Bruno, Calif.
Golden West Chapter	1	E. Bloton Electric Service League of Sask. 203 Kerr Bldg. Regina, Sask. AND Miss Lillian Vigrass Saskatchewan Power Corp. 1739 Cornwall St. Regina, Sask.
Hamilton, Ontario Chapter	1	
Heart of America Section	2	Gordon McDonald 5095 Osceola St. Denver, Colo.
Indiana Section	2	W. H. Smith Electrical Equipment Co. 20 S. Senate Indianapolis, Ind.
Inland Empire Chapter	1	Ron Giedt Columbia Electric & Mfg. Co. P.O. Box 2180 Spokane, Wash.
Iowa Section	2	J. C. Young 2400 E Ave., N. E. Cedar Rapids, Ia.
Maritime Chapter	1	E. J. Wilcox 20 Alexander St. St. John, N. B.
Maryland Section	2	G. W. Younglove Baltimore Gas & Electric Co. 1012 Lexington Bldg. Baltimore, Md.
Miami Valley Section	1	Gary Roof Leader Electric Co. 4525 Twilight Hill Drive Dayton, Ohio.
Michigan Section	4	Lloyd A. Crotser Westinghouse Electric Corp. 5757 Trumbull Detroit, Mich.
Mid-South Chapter	1	H. G. McMullen Memphis Light Gas & Water Div. 179 Madison Memphis, Tenn.
Milwaukee Section	3	J. C. Augustine 3885 N. Humboldt Milwaukee, Wis.
Mississippi Chapter	1	L. H. Hickman 115 Woodsea Lane Jackson, Miss.
Montreal Section	2	B. J. Monaghan Peerless Electric, Ltd. 5585 Fullum Montreal, Que.
Mother Lode Chapter	1	Charles D. Gibson Div. of Public School Administration Dept. of Education 721 Capitol Ave. Sacramento, Calif.
New England Section	5	David L. Marx 25 Dodge Road Hyde Park, Mass.
New Jersey Section	3	A. S. Robinson 369 Lake Ave. Colonia, N. J.
New Mexico Chapter	1	Albert W. Boehning, Jr. Boehning & Boehning 1841 Lomas Blvd. Albuquerque, N. M.
New Orleans Section	2	Edward R. Tschirn New Orleans Public Service Dept. 317 Baronne St. New Orleans, La.
New York Section	6	Robert Nolan General Electric Co. 570 Lexington Ave. New York, N. Y.
North Texas Section	2	Wm. G. McKeithen 3813 Eldridge Ft. Worth, Texas.
Northwestern Ohio Section	1	Scott Nagel 1657 Stanbery Ct. Toledo, Ohio.
Ohio Valley Section	2	Beattie M. DeLong 52 Woodland Ft. Thomas, Ky.
Oil Capital Section	1	Clarence H. Dollmeyer 4232 So. Peoria Tulsa, Okla.
Oregon Section	2	Mrs. Grace C. Schoeni Portland General Electric Co. 621 S.W. Alder St. Portland, Ore.

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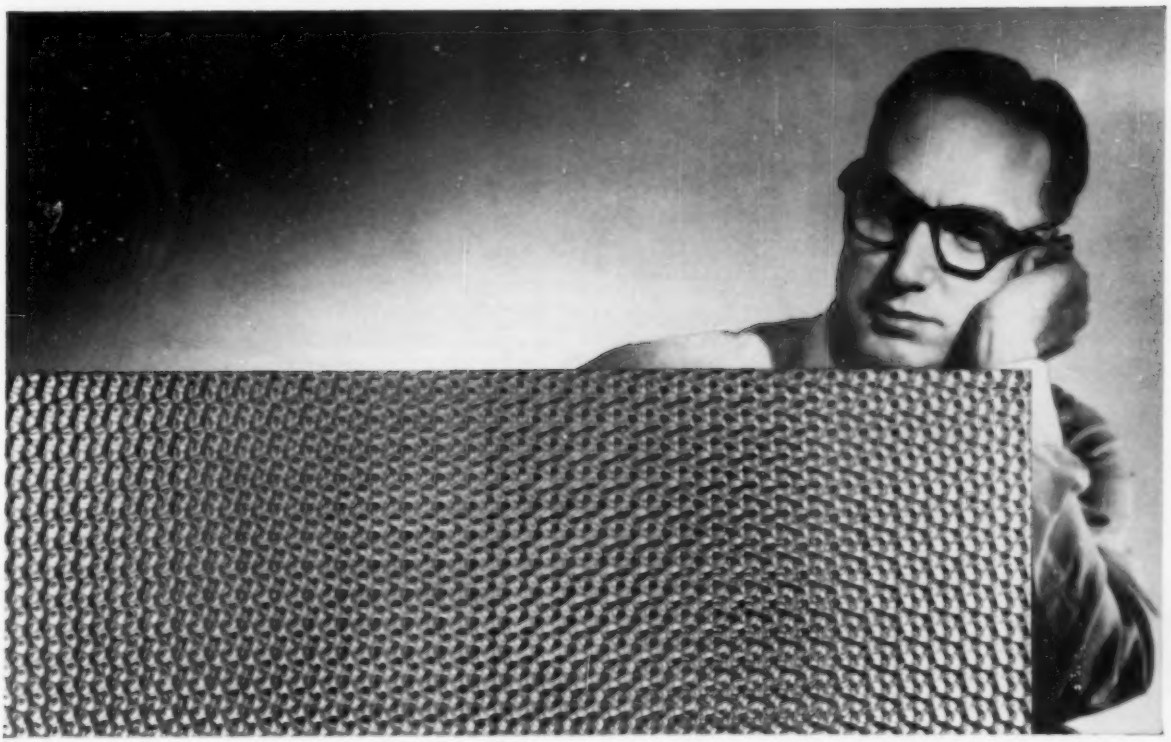
CRYSTOPAL 71



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When you want soft, diffuse light, but still require high-level illumination with brightness control, call for Crystopal No. 71. A new concept in lighting glassware, it combines a water-white crystal for prismatic control with a small amount of opal for diffusion—all in a single, lightweight panel.

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The partial opal reduces reflected glare, offering better panel obscurity of the light sources.

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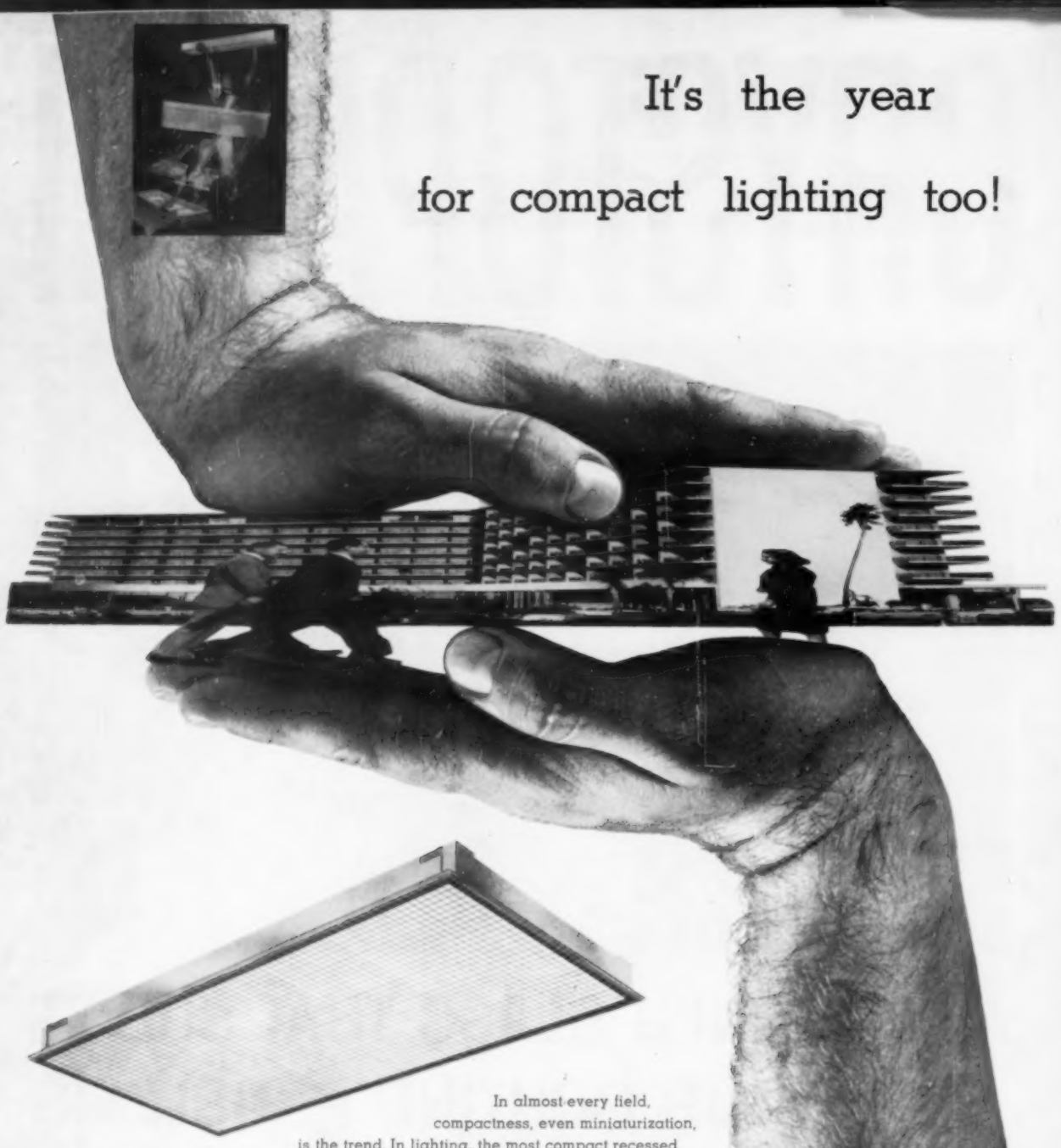

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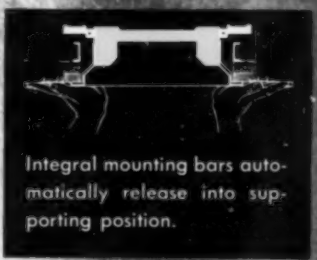

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(*Lighting News continued from page* 16A)

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(*Lighting News continued on page* 20A)

(*Lighting News continued from page 19A*)

ABOUT PEOPLE

The appointment of **Herman L. Weiss** as general manager of the General Electric Co.'s Lamp Division, with headquarters at Nela Park, Cleveland, Ohio, was announced recently. Mr. Weiss, formerly general manager of the Large Lamp Department, succeeds vice-president **George E. Burens** who is being transferred to a special assignment in the company's Consumer Products Group in New York City.

Carl M. Holden, formerly associated with Champion Lamp Works, Lynn, Mass., has joined the staff of Vorlander Lighting, Boston, in a sales engineering position. He will have his office at the firm's Boston headquarters.

Six new regional sales managers have been appointed by the Appleton Electric Co., Chicago, Ill., as a result of extensive Sales Department reorganization. **E. A. McNeill** has been assigned the Northeastern sales region, with offices in N.Y.C. **Z. B. Greer,** working out of Birmingnam, Ala., takes over the Southeastern area. The East Central region, including Michigan, Ohio, Indiana, Pennsylvania, Kentucky and part of West Virginia, will be controlled by **W. G. Crum,** with headquarters in Detroit. **E. A. Hakanson,** Skokie, Ill., has been assigned the North Central territory, which includes Illinois, Wisconsin, Minnesota, North and South Dakota and parts of Iowa and Indiana. The South Central sales region will be covered by **H. T. White,** from offices in Kansas City. **H. A. Buegel,** San Francisco, Calif., is assigned the Western sales district.

Robert C. Simmons has joined the Curtis Lighting Division, Curtis-AllBrite Lighting, Inc., Chicago, Ill., as sales representative for the Rochester territory, according to an announcement by **Frank J. Bernd,** general manager. For the past ten years, Mr. Simmons has been associated with the General Electric Supply Co. in a sales capacity. The appointment of **John W. Wolfe** as sales representative for the Curtis-AllBrite Cincinnati territory has also been announced. Mr. Wolfe has been a sales representative for AllBrite Fluorescent Fixtures in California for the past several years; prior to that, he was electrical estimator for North Bay Electric Co., San Rafael, Calif.

Ferris J. Abbass has been appointed superintendent of the Nova Scotia Power Commission's commercial department. Mr. Abbass, who joined the commission staff as assistant superintendent of the commercial department in 1957, was formerly associated with Maritime Engineering Consultants, Canadian Westinghouse and the New Brunswick Electric Power Commission. He replaces **L. F. Kirkpatrick,** who has been named assistant manager. In another commission appointment, **Arnold W. Sarty** succeeds **C. N. Bates** as secretary-treasurer.

Ralph F. Thompson, Jr. has been promoted to manager of the appliance and equipment market for Reynolds Metals Co. Mr. Thompson's headquarters will be at the company's general office in Richmond, Va.

The appointment of **Stanley M. Diamond** as Ontario division manager has been announced by Red Comet of Canada, Ltd. Formerly Eastern division manager, Mr. Diamond has served in responsible company positions since 1954.

Howard M. "Buck" Buchholz has been named manager, Commercial Time Switch Division of the Paragon Electric Co. He succeeds **Warren L. Peterson,** now manager of Paragon's West Coast office in Los Angeles, and will operate out of the company's main offices in Two Rivers, Wis.

The Board of Directors of the American Institute of Electrical Engineers has elevated 10 members to the grade of Fellow for outstanding contributions to the profession. Those so honored are: **Edwin C. Ballman,** chairman of the board, Baldor Electric Co., St. Louis, Mo.; **Willard R. McCarty,** supervisor of electrical engineering, Department of Research and Development, Wagner Electric Corp., St. Louis, Mo.; **Randolph W. Burrell,** senior engineer, Outside Plant Bureau, Consolidated Edison Co., N. Y.; **Joseph S. Johnson,** professor of electrical engineering and dean of the College of Engineering, Wayne State Univ., Detroit, Mich.; **Walter K. MacAdam,** assistant chief engineer, American Telephone and Telegraph Co., N. Y.; **Alfred L. Pollard,** operating manager, Puget Sound Power & Light Co., Bellevue, Wash.; **Ralph E. Thornton,** superintendent of engineering, Oklahoma Gas and Electric Co., Oklahoma City, Okla.; **Harold Torgersen,** professor of electrical

(*Continued on page 30A*)

Charles C. Munroe—A Tribute

Charles C. Munroe was born in Detroit on October 10, 1883. He began his 47-year career with The Detroit Edison Co. in June 1901, when he was hired as an office boy and night telephone clerk. In 1903 he was promoted to clerk and in 1905 to solicitor, which meant that he was assigned to build lighting business in the downtown Detroit area. In this position, Charlie Munroe was probably the company's first lighting salesman, with the job of selling electric lighting in competition with the prevalent gas mantel.

Perhaps he first recommended arc lights or Nernst lamps to his customers. Arc lights are still in use for motion picture projection and searchlights; the Nernst lamp was an earthenware rod heated to incandescence by an electric current. His most effective weapon against the gas lights, however, was a four-light cluster consisting of four 32-candlepower carbon lamps and a reflector. In about 1910, tungsten lamps appeared and by 1916, they had essentially replaced carbon sources.

The Illuminating Engineering Society was founded in 1906 and came to Detroit in 1923 when Charles C. Munroe and James Ketch of General Electric organized the first IES Chapter in Detroit. Jim Ketch was the Chapter's first Chairman; Charlie Munroe, its second. For many years his name was synonymous with IES in the Detroit area.

During most of his career at Detroit Edison, Charlie Munroe was in charge of the Sales Department Lighting Division and played a large part in the ever-increasing public acceptance of good lighting practice. He retired on November 1, 1948, with good wishes and hundreds of friends.

His son, Charles C. Munroe, Jr., better known as "Bill," also had a notable career in the lighting field. For the past several years Bill was the Michigan representative for the Edwin F. Guth Co., St. Louis, Mo. As Charlie's health failed in recent years, Bill became more and more his mainstay. It was a real tragedy to Charlie Munroe and all his friends, when Bill died suddenly on August 18, 1959.

Father survived son by less than three months. Charles C. Monroe, Sr., died on November 11, 1959.

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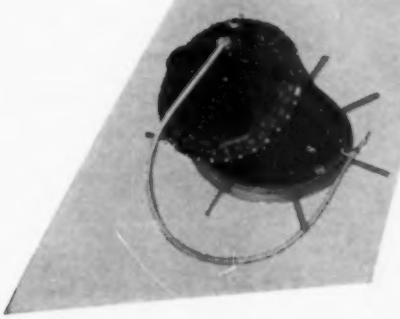

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In general, the information contained in these Recommended Lighting Practices covers completely the area shown in the title. Included in the data are suggested types of lighting systems and luminaires; levels for general lighting and for specific areas; analyses of seeing tasks; and other information essential to lighting the area and of value to lighting engineers and specialists, architects, construction people and others. Each practice is fully illustrated with charts and photographs.

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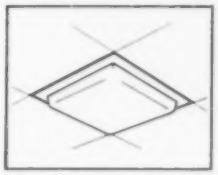
Louisville:
Henry J. Ruoff Co.
LOUISIANA
Baton Rouge:
Electrical Wholesalers Inc
New Orleans:
Interstate Elec. Co.
MAINE
Bangor:
Standard Elec. Co.
Portland:
Holmes Elec. Supply Co.
MARYLAND
Baltimore:
Excello Public Serv. Corp.
Salisbury:
Arkcraft Elec. Sup. Co.
MASSACHUSETTS
Boston:
Mass. Gas & Elec. Light Co.
Henry L. Walters, Inc.
Pittsfield:
Carr Supply Co.
Springfield:
Eastern Elec. Sup. Co.
Worcester:
Atlantic Elec. Sup. Co.
Benjamin Elec. Sup. Co.
MICHIGAN
Detroit:
Madison Elec. Co.
Michigan Chandelier Co.
Flint:
Royalite Co.
Grand Rapids:
Purchase Elec. Sup. Co.
Jackson:
Electric Wholesale Sup. Co.
Pontiac:
Standard Elec. Co.
Saginaw:
Schmeerbeck Elec. Co.
Standard Elec. Sup. Co.
MINNESOTA
Duluth:
Northern Elec. Sup. Co.
Minneapolis:
Charles A. Anderson & Co.
Northland Elec. Sup. Co.
St. Paul:
Lee Elec. Co.
MISSOURI
Kansas City:
Crasco Elec.
St. Louis:
W. R. Clark
MONTANA
Great Falls:
Glacier State Elec.
NEBRASKA
Lincoln:
White Elec.
Omaha:
Electric Fix. & Sup. Co.
NEVADA
Reno:
Western Elec. Dists. Co.
NEW HAMPSHIRE
Portsmouth:
Mass. Gas & Elec. Light Co.
NEW JERSEY
Atlantic City:
Franklin Elec. Sup. Co.
Cherry Hill:
Delaware Township:
Flynn's Camden Elec. Fix. Co.
NEW MEXICO
Albuquerque:
The Lighting and Main, Co.
NEW YORK
Binghamton:
Frank Elec. Sup. Co.
Buffalo:
Buffalo Incand. Light Co. Inc.
Niagara Falls:
Hysen Supplies Inc.

NEW YORK (cont.)
Poughkeepsie:
Electra Sup. Co.
Rochester:
Rowe Electric Sup. Co.
Syracuse:
Superior Elec. Corp.
NORTH CAROLINA
Charlotte:
Independent Elec. Sup. Co.
Durham:
Noland Co.
Greensboro:
Elec. Sup. & Equip. Co.
Kinston:
Kinston Elec.
Winston Salem:
Noland Co.
NORTH DAKOTA
Fargo:
Northwest Elec. Sup. Inc.
OHIO
Akron:
The Sacks Elec. Sup. Co.
Canton:
Electric Sales Co.
Cincinnati:
B. & B. Elec. Co.
F. D. Lawrence Electric Co.
Richards Elec. Sup. Co.
Cleveland:
The H. Leff Electric Co.
Midland Elec. Co.
Columbus:
Elgee Elec. Co.
The Loeb Elec. Co.
Dayton:
Duellman Elec. Co.
Springfield:
The W. W. Elec. Co.
Toledo:
Gross Elec. Fix. Co.
Youngstown:
Mart Industries
OKLAHOMA
Oklahoma City:
Elec. Sup. of Oklahoma
OREGON
Portland:
Baker-Barbon Co.
Malloy Robinson Co.
PENNSYLVANIA
Allentown:
Coleman Elec. Co.
Erie:
Kraus Elec. Co.
Harrisburg:
Fluorescent Sup. Co.
Hazleton:
Power Elec. Co. Inc.
Kingston:
Anthracite Elec.
New Castle:
Midwestern Elec. Co.
Philadelphia:
Ace Lighting Fix. Co.
Gold Seal Elec. Sup. Co.
Sylvan Elec. Fix. Co.
Pittsburgh:
Allied Elec. Sup. Co.
Argo Lite Studios
Reading:
Coleman Elec. Co.
Scranton:
Lewis & Reif, Inc.
Uniontown:
Pioneer Electric Dist.
RHODE ISLAND
Pawtucket:
Major Elec. Sup. Co.
Providence:
Leavitt Colson Co.
SOUTH CAROLINA
Columbia:
Capitol Elec. Sup.
Noland Co.
Greenville:
Sullivan Hdwe. Co.
SOUTH DAKOTA
Watertown:
J. H. Larson Elec. Co.
TENNESSEE
Nashville:
Nashville Elec. Sup. Co.
TEXAS
Austin:
Southern Electric Sup. Co.
Dallas:
Rogers Elec. Sup. Co.
Ft. Worth:
Anderson Fixture Co.
Houston:
Gross Electric Supply
Marlin Associates
Southern Electric Supply Co.
Lubbock:
Homer G. Maxey & Co.
San Antonio:
Southern Equip. Co.
Strauss-Frank Co.
UTAH
Salt Lake City:
Artistic Lighting
VIRGINIA
Arlington:
Dominion Elec. Sup. Co. Inc.
Noland Co.
Lynchburg:
Mid-State Elec. Sup. Co., Inc.
Norfolk:
Noland Co.
Roanoke:
Noland Co.
WEST VIRGINIA
Huntington:
West Virginia Elec. Co.
Wheeling:
The Front Co.
WISCONSIN
Appleton:
Moe Northern Co.
Eau Claire:
W. H. Hobbs Sup. Co.
Milwaukee:
Lappin Elec. Co.
Standard Elec. Sup.
WASHINGTON
Seattle:
Seattle Lighting Fix. Co.
ALASKA
Anchorage:
Northern Supply Co.
CANADA
Montreal:
L. D. G. Products, Inc.
The Gray Elec. Co.
Union Electric Sup. Ltd.
Quebec City:
La Cie Martineau Electric Co.
Toronto:
Revere Elec. Dist.
Toronto Ltg. Studios
HAWAII
Honolulu:
Hawaiian Light & Sup. Co.

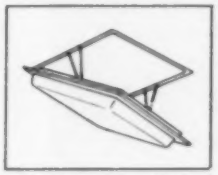
Three sound reasons for specifying

CALCULITES by LIGHTOLIER

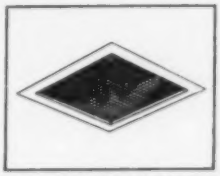
This new coordinated, quality group fits nearly any downlighting need and does it 1. attractively, 2. efficiently and 3. effectively. Example: the Calculite below articulates the ceiling-fixture joint with an opaque metal skirt. The albalite diffuser sends a flood of illumination to the working surfaces. Available: seventeen other models, 96 sizes and finishes, round and square shapes, for wide, medium and narrow light distribution.



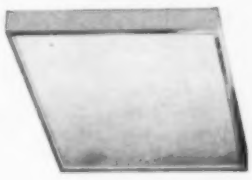
Calculites complement your precision detailing. Example: the new formed glass unit above exactly replaces a 12" x 12" ceiling tile, fits perfectly flush with the finished ceiling surfaces.

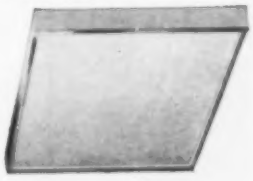


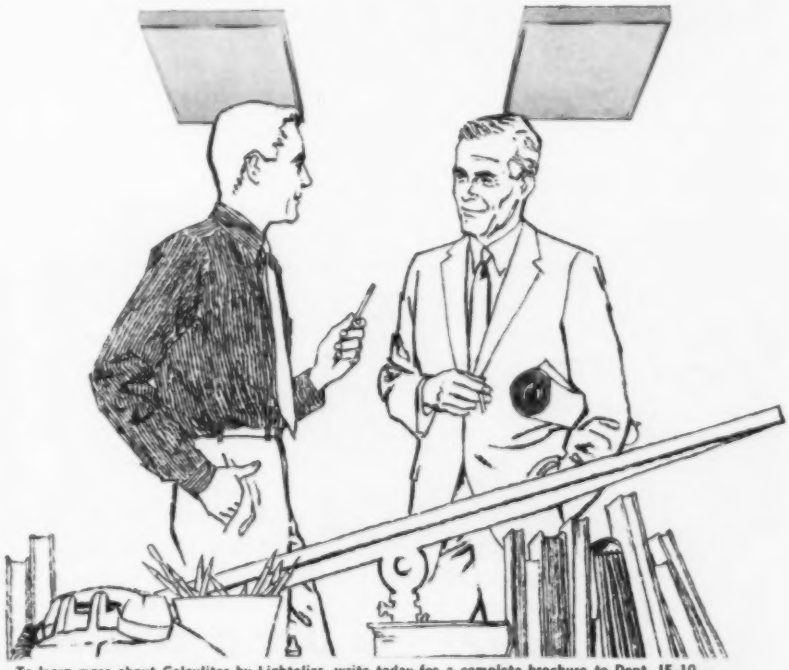
Calculites are efficient lighting instruments. Example: Torsiontite spring above permits safe, easy relamping, pulls down from any side. Foam gaskets provide tight seal.



For a simple low-brightness unit exactly flush to the ceiling plane choose the Prismatex Calculite above. In baked white enamel or weatherproof anodized satin aluminum.







To learn more about Calculites by Lightolier, write today for a complete brochure to Dept. IE-10

LIGHTOLIER

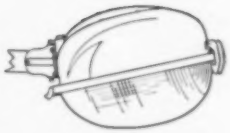
Jersey City 5, New Jersey — Showrooms: New York, Chicago, Dallas, Los Angeles

Revere Outdoor Lighting Report

Lighting a city street

The Problem: To illuminate a wide city street uniformly across the total width with high-level light, thus providing fast-moving traffic with utmost visibility for safety.

The Solution: Revere Endoval Luminaires with 400-watt mercury lamps were mounted at 10° tilt on both sides of the wide street, staggered. Distribution pattern selected was I.E.S. Type III which provided uniform light across the entire width of the street, giving the high visibility desired for safe, smooth traffic flow. There is adequate spill light to illuminate sidewalks and parked cars. Endovals mount horizontally if desired.

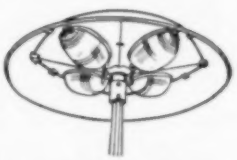


No. 2200 Series
Endoval Luminaire

Lighting a shopping center parking lot

The Problem: To provide high night-visibility for a large shopping center parking lot for ease and safety in driving, parking, and locating parked cars, and to make the shopping center more inviting.

The Solution: High-level, uniform lighting was achieved with 187 Revere 72-inch diameter Ultra-Lites, mounted 34 feet above grade. They use four E-H1 400-watt mercury lamps each, positioned for widest coverage and highest illumination level. Ultra-Lites throw square light patterns which overlap to eliminate "dark spots" and to build up light values in fringe areas.

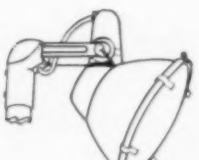


No. 5442 Ultra-Lite

Lighting a flight line

The Problem: To illuminate the wide expanse of a flight line so that routine aircraft operations could be carried on at night with complete convenience and safety.

The Solution: To light the broad flight line intensely and uniformly, 1800 Revere Alzak Aluminum Enclosed Floodlights were used. They were mounted on thirty 80-foot poles, each pole having two banks of 30 floodlights. Each bank has 12 wide-beam floodlights (No. 4211-P) and 18 narrow-beam floodlights (No. 4216-P), with 1500-watt P.S. 52 clear, general-service lamps.



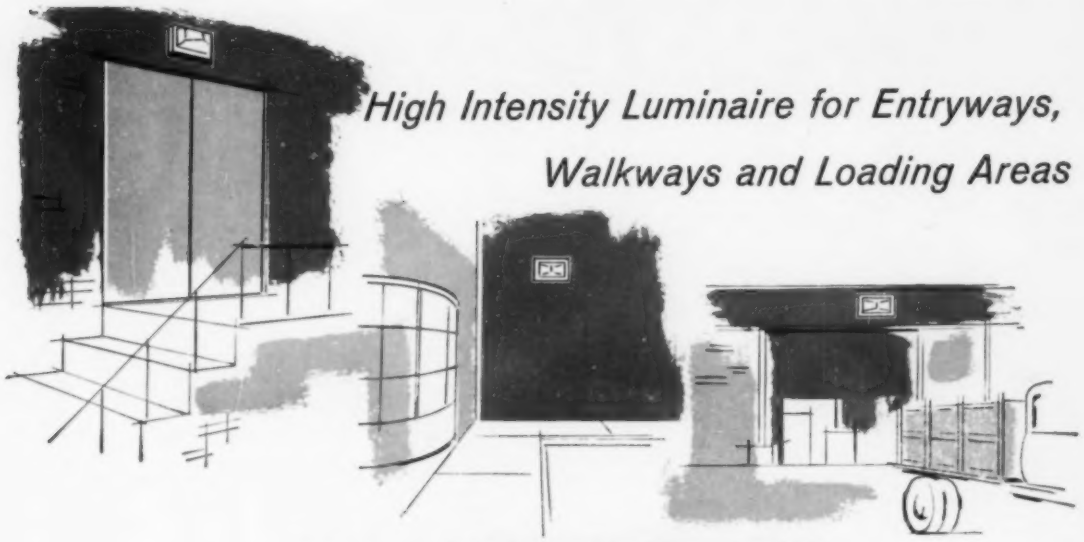
No. 4200
Series Floodlight

Write for Revere's complete catalog of outdoor lighting equipment.

Revere ELECTRIC MFG. CO.

OUTDOOR LIGHTING

Revere Electric Mfg. Co. • 7420 Lehigh Avenue • Chicago 48, Illinois (In suburban Niles)
Long Distance Phone: NIles 7-6060 • Chicago Phone: SPring 4-1200 • Telegrams: WUX Niles
In Canada: Curtis Lighting, Ltd., Leaside, Toronto, Ontario



High Intensity Luminaire for Entryways, Walkways and Loading Areas

The PERFECLITE "PHAROS"

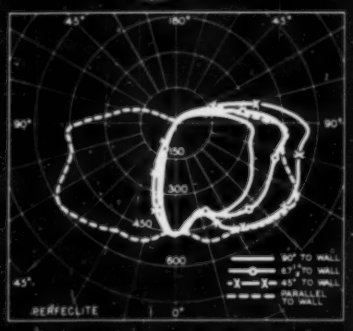
A Totally New Concept In Controlled Exterior Illumination

Another first from Perfeclite! A modular shaped lighting fixture that completely outmodes the usual exterior bracket extending on a heavy arm from the wall.

Ultra-modern in design, the new Pharos gives an asymmetric light pattern . . . provides high intensity illumination for wall areas . . . disperses a powerful outward distribution of light 90° from the wall as well. The heat-resistant glass refractor uses accurately calculated prisms on seven transmission surfaces . . . incorporates a silvered glass reflector at the top which directs the light downward.

Made of cast aluminum, gasketed and weatherproofed, the Pharos opens on concealed hinges for easy relamping, easy maintenance. It is rated at 200 watts, utilizing a standard A-25 lamp.

For further information, mail the attached coupon today!



CANDLEPOWER DISTRIBUTION
200 W. A-25 I. F. LAMP
E. T. L. REPORT NO. 372483

Units are Underwriters' Laboratories Inc. approved.

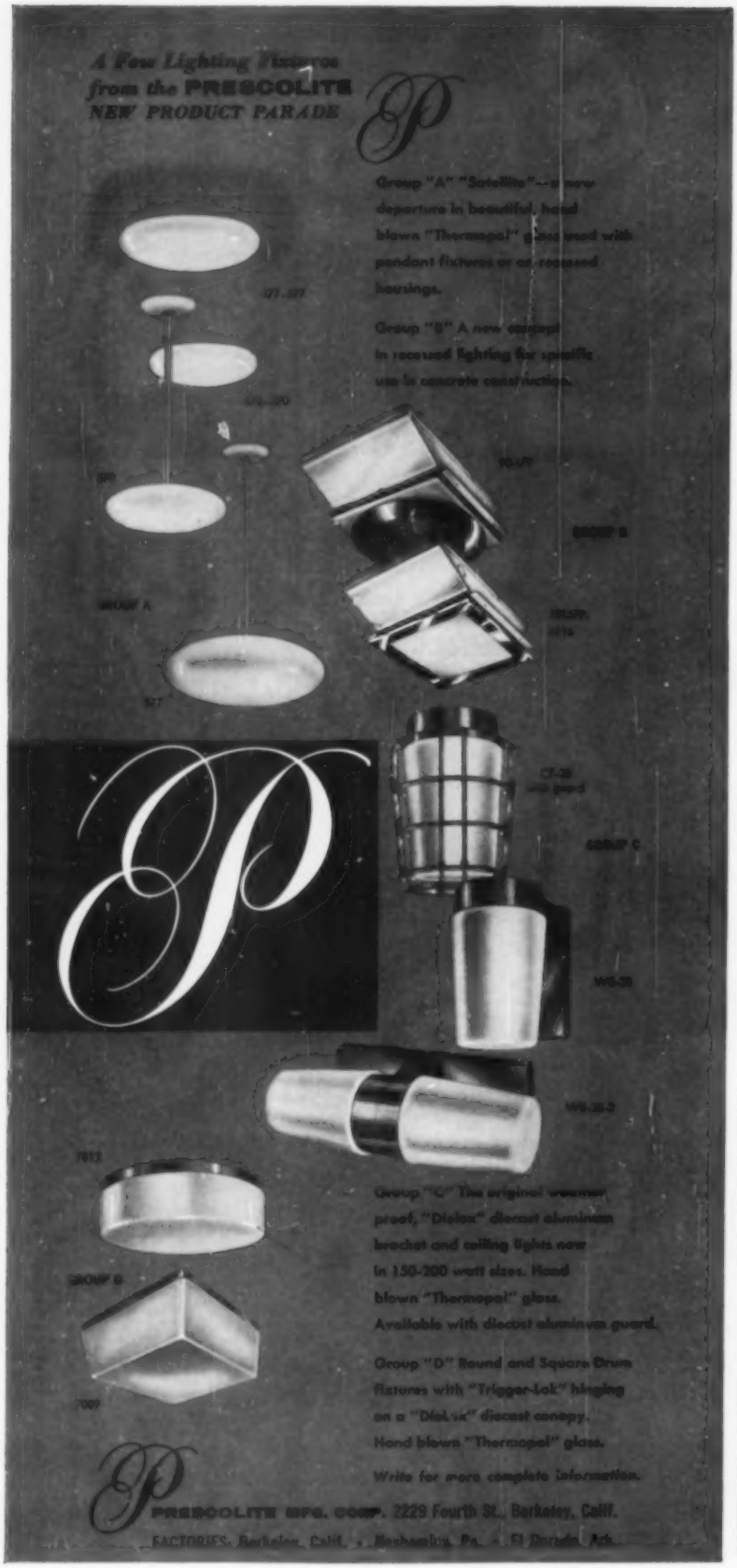
THE PERFECLITE COMPANY
1457 East 40th Street Cleveland 3, Ohio

Please send me the Perfeclite Data Folder 59-C.

NAME _____

ADDRESS _____

CITY _____ STATE _____


A Few Lighting Fixtures
from the PRESCOLITE
NEW PRODUCT PARADE
Group "A" "Satellite"—a new departure in beautiful, hand blown "Thermopal" glass used with pendant fixtures or as recessed housings.
Group "B" A new concept in recessed lighting for specific use in concrete construction.
Group "C" The original weather proof, "Dialux" diecast aluminum bracket and ceiling lights now in 150-200 watt sizes. Hand blown "Thermopal" glass. Available with diecast aluminum guard.
Group "D" Round and Square Drum fixtures with "Trigger-Lok" hinging on a "Dialux" diecast canopy. Hand blown "Thermopal" glass.
Write for more complete information.
PRESCOLITE MFG. CORP. 2229 Fourth St., Berkeley, Calif.
FACTORIES: Berkeley, Calif. • Bensenville, Ill. • El Dorado, Ark.

(Continued from page 20A)

engineering and dean, School of Engineering, Univ. of Connecticut, Storrs, Conn.; **Asa H. Myles,** chief engineer, Electric Controller & Manufacturing Division, Square D Co., Cleveland, Ohio; **Walter R. Wilson,** manager of engineering, High-Voltage Switchgear Department, General Electric Co., Philadelphia.

Earl N. Picker has been named sales promotion manager for Day-Brite Lighting, Inc., St. Louis, Mo. He joined Day-Brite in 1945 as an engineering department draftsman. He later worked as an artist in the advertising department and, when the growth of the company necessitated expansion of this department, he became art director. His duties in this capacity included designing and supervising the building of company trade show displays. At present, in addition to his new responsibilities, he is acting marketing services manager while this position is unfilled.

Peerless Electric Ltd., Montreal has announced the appointment of **B. J. Monaghan** as Canadian sales manager. Mr. Monoghan, formerly senior illumination specialist for the Northern Electric Co. Ltd., has been active in the lighting industry for the past ten years.

Charles J. Meloun has been appointed as manager of marketing for General Electric's Outdoor Lighting Department at Hendersonville, N. C. Mr. Meloun has served as manager of engineering for the department for the past three years. **Philip D. Reed,** who last year stepped down as chairman of the board of the General Electric Co., retired November 30. He has been associated with G-E for 33 years.

The appointment of **Philip Scharf, Jr.** as promotion manager—panelboards and switchboards has been announced by Merle P. Spurrell, director of sales of the BullDog Electric Products Division of I-T-E Circuit Breaker Co. Mr. Scharf, manager of order services since 1951 and a 19-year veteran with BullDog, has served in various capacities in the engineering and sales sections of the firm.

The Westinghouse Lamp Division, Bloomfield, N. J., has a new Brooklyn district sales manager in **Oscar Poulson, Jr.** Mr. Poulson, whose office will be located in Richmond Hill, will be responsible for all of the company's lamp sales in the Brooklyn area. In addition, **Carlyle O. Young** has been appointed manager of metallurgical engineering for the same division, according to an announcement by Dr. Rolland M. Zabel, lamp di-

(Continued on page 33A)

Sylvania **controlled** fluorescents win contract to light Panama Canal's famed Gaillard Cut!

In the Panama Canal's critical Gaillard Cut, other lighting systems tested reflected on the water, blinding ship pilots who strained to see the banks.

Sylvania beat competition by lighting the *banks*, not the water! With low mounting, sharp definition–no reflections! Pilots can see perfectly. Now at last, in the Gaillard Cut, ships can pass in the night!

Sylvania used VHO Reflector power tubes, 8 feet long, delivering the greatest reflected brightness of any fluorescent made! Standing 65 feet apart in Sylvania-developed CFR (Controlled Fluorescent Reflectance) mounts, they throw an unbroken white wall of light up the embankments.

This is just one more example of how Sylvania lighting engineers work to give you superior lighting at lowest possible TCL (Total Cost of Lighting), which means cost of lamp plus power plus maintenance. As a result Sylvania gives every user an exclusive Light Insurance Policy *guaranteeing* more light at lower cost than other brands–or your money back!

Sylvania-developed VHO-CFR system used in Panama Canal, also on airfields, billboards, in industry.

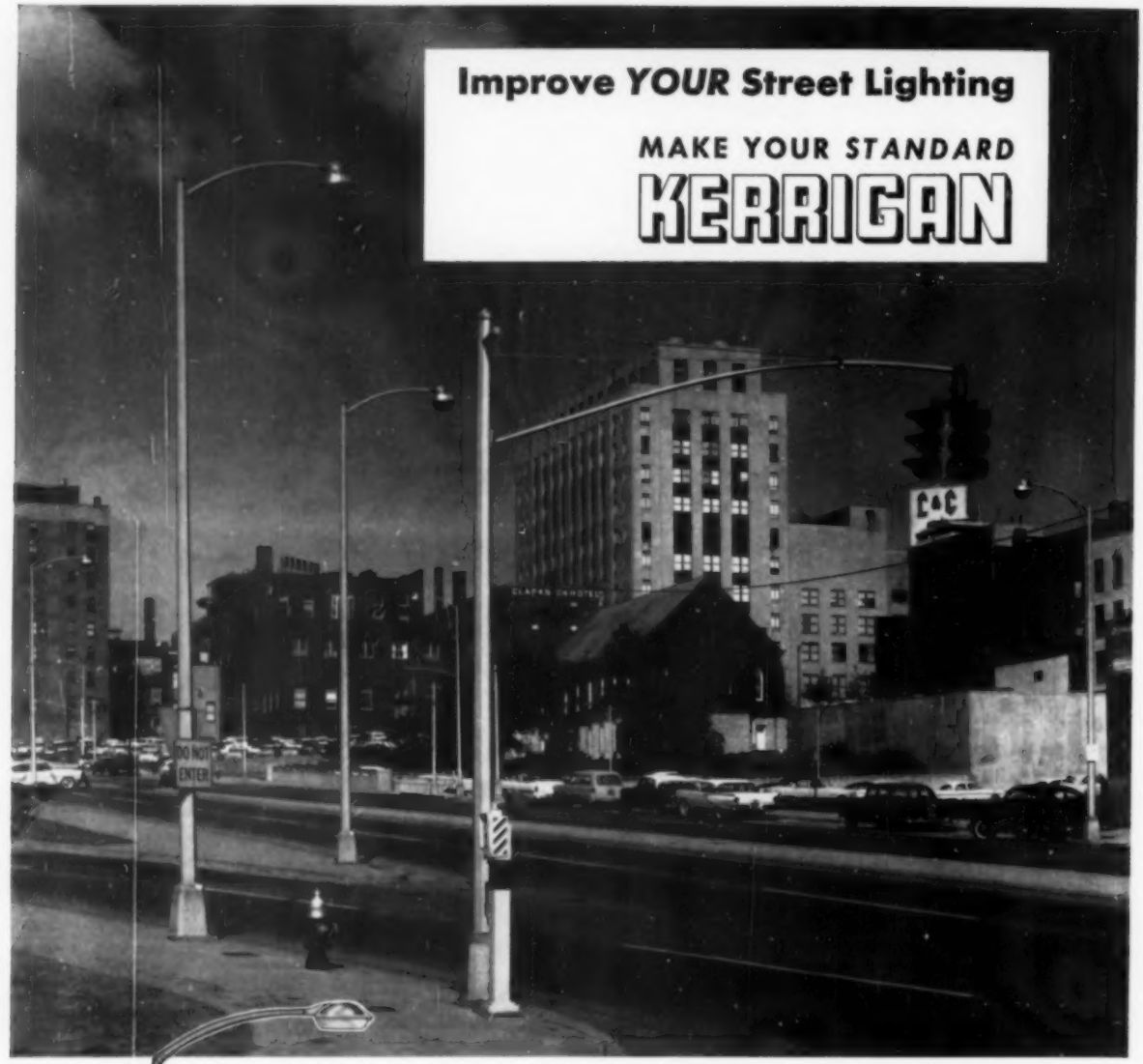
• • •

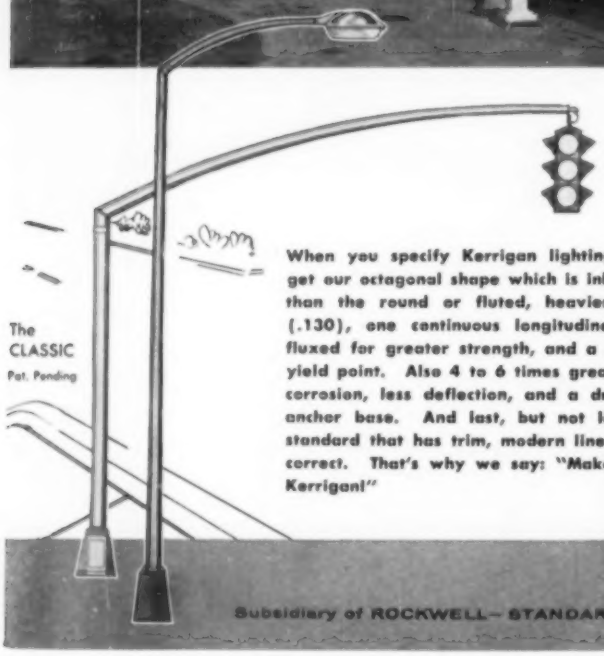
The Panama Canal Co. enjoys this insurance. Do you? Call your Sylvania representative, or write us: *Sylvania Lighting Products, a Division of Sylvania Electric Products Inc., 60 Boston St., Salem, Mass. In Canada: Sylvania Electric (Canada) Ltd., P. O. Box 1190, Station "O," Montreal 9.*

SYLVANIA

Subsidiary of

GENERAL TELEPHONE & ELECTRONICS





When you specify Kerrigan lighting standards you get our octagonal shape which is inherently stronger than the round or fluted, heavier wall thickness (.130), one continuous longitudinal weld magna-fluxed for greater strength, and a guaranteed high yield point. Also 4 to 6 times greater resistance to corrosion, less deflection, and a drop forged steel anchor base. And last, but not least, you get a standard that has trim, modern lines, architecturally correct. That's why we say: "Make Your Standard Kerrigan!"

Our new 70-page catalog has the engineering facts on both steel and aluminum standards! Won't you write for your FREE copy now? Address: Dep't. IE-1.

KERRIGAN
IRON WORKS COMPANY
Nashville, Tennessee

Subsidiary of ROCKWELL–STANDARD Corporation

(*Continued from page* 30A)

vision engineering manager. Mr. Young, who was formerly associated with Sylvania as manager of metallurgical engineering, will list among his new responsibilities the broad metallurgical problems involved in lamp manufacture, especially in the field of tungsten and molybdenum, which are vital components of incandescent lamps.

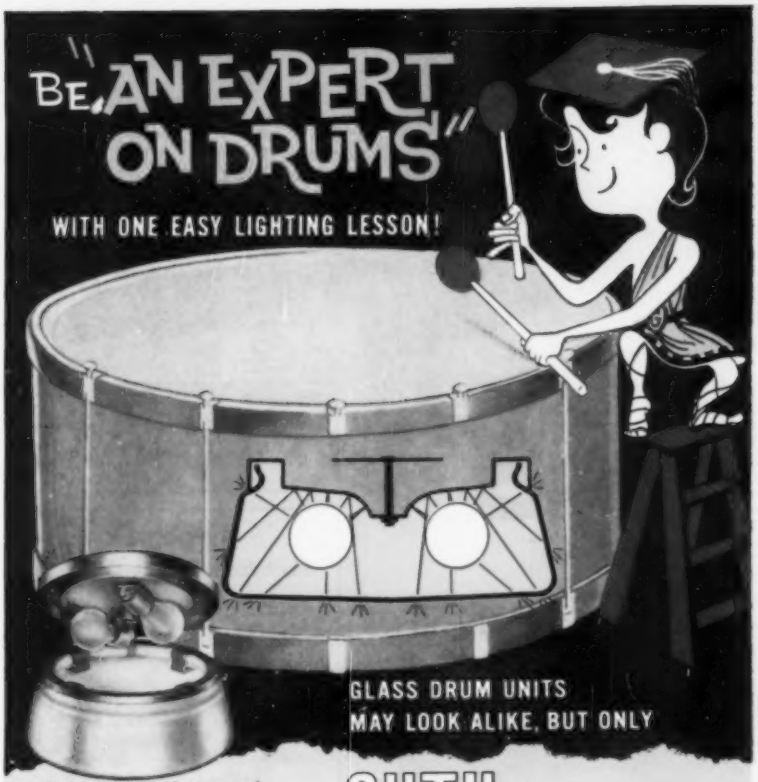
The RLM Standards Institute held its annual meeting on October 28, at which time three trustees were elected; officers were chosen at the Board of Trustees meeting held later that day. Those selected are: **E. C. Huerkamp,** president and trustee, Westinghouse Electric Corp., Cleveland, Ohio; **L. A. Hobbs,** vice president and trustee, Smoot-Holman Co., Inglewood, Calif.; **E. F. Mulligan,** treasurer and trustee, Jones Metal Products Co., West Lafayette, Ohio; **C. S. Putnam,** secretary and trustee, Wheeler-Fullerton Lighting Division, Franklin Research Corp., Boston, Mass.; **A. C. Kendall,** trustee, Sylvania Electric Products, Inc., Fixture Division, Wheeling, W. Va.; **D. E. Worrell,** trustee, Quadrangle Mfg Co., Chicago, Ill., and **O. A. Zumwalt,** trustee, Thomas Industries, Inc., Louisville, Ky.

On December 1, after 46 years of service, **Herbert S. Loud** retired from the Detroit Edison Co., Detroit, Mich. Mr. Loud started with the company as an electrician in the construction department and worked as a substation operator for several years before being assigned duties in the buildings and properties department in 1920. In 1948 he was named electrical foreman for that department, a position he held until his retirement.

The formation of an agency to represent electrical manufacturers in the Memphis trade area has been announced by **James Clary,** former sales manager for Light & Power Utilities Corp., Memphis, Tenn. The agency will operate under his name and will represent Light & Power in addition to other lines. Mr. Clary has previously been associated with the Memphis Light, Gas & Water Division as lighting engineer, and was a salesman with Graybar Electric Co. before joining Light & Power.

J. Scribner Allen has been appointed sales representative in Washington, D. C., for the Edison Electric Institute Sales Division, according to an announcement by Edwin Vennard, vice president and managing director of the Institute. Mr. Allen was formerly employed by the American & Foreign Power Corp., where for three years he served as a consult-

(*Continued on page* 34A)



Swingaway maintenance! Hinged ring and chain for easy relamping and cleaning.

OTHER DRUM UNITS

B 1215 Long-Boy Ellipse; intense narrow-beam light, specular Alzak reflector

B 1210 Metal drum units, concave prismatic lens with genuine Alzak reflectors.

B 1192 Prison and psychiatric units; cast guard, shatter-proof prismatic lens, tamper-proof screws.

B 1618 Gym drum units, with guard or louver, single to quadruple mountings.

GUTH BRASCOLITES

HAVE HIGH EFFICIENCY, CONTOUR ALZAK REFLECTORS

Real parabolic-design provides permanent, efficient light control. Unlike flat-pan or aluminum-foil types, Alzak contour reflectors can't come ungluded, tarnish, or become permanently discolored from lamp heat. Super white opal glassware has satin-finish ceiling ring. Unit gives excellent downlight, plus good ceiling illumination above and around the fixture. Models to accommodate up to three 100-watt lamps. Complete selection available.

Guth LIGHTING since 1902

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THE EDWIN F. GUTH COMPANY • ST. LOUIS 3, MISSOURI

NEW
98
line
weatherproof
fluorescent

extruded aluminum
enclosed and gasketed
waterproof • corrosion resistant

For tunnels · underpasses · airport ramps subways · loading docks · station terminals laboratories · chemical industries · garages piers · service stations · swimming pools and marine applications.

High corrosion resistance combined with strength . . . low brightness with Holophane compound Controlens® . . . new wiring economy with extra large wire channels . . . Choice of High Output Rapid Start or Slimline · available in 4, 6, 8 ft. individual lengths · or in continuous runs.

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LIGHTING
1329 Willoughby Ave., Brooklyn 37, N. Y.
in Canada: mcPhilben division of
Wakefield Lighting Ltd. London, Ontario

your McPhilben representative has a 98 Line sample unit . . . ask to see it.
Sweet's 33a Mc

(*Continued from page 33A*)

ant for sales and area development. Prior to that he was with the General Electric Co. for ten years as a sales engineer and product sales specialist in their producer goods department. In his new post, Mr. Allen will be available to provide information to government agencies in connection with the supply and application of electricity for various projects and developments.

The purchase of Hutchinson Manufacturing Co., Houston, Texas, by Revere Electric Mfg. Co., Niles, Ill., has been announced by **Murray J. Whitfield,** president of Revere. The Houston company, which will operate as a subsidiary of Revere, retains **Judson Smith** as president and Mr. Whitfield becomes chairman of the board.

Lynn W. Ferguson, who retired this past year after devoting 40 years to the lighting industry, is now residing in Bradenton, Fla. The past-president of the Virginia Section plans to spend some of his newly-found leisure time attending Florida Section meetings.

EMPLOYMENT OPPORTUNITIES

Wanted

Manufacturer's Representatives

Manufacturer of nationally advertised quality line of competitively priced commercial and industrial fixtures having architect-engineer-utility-contractor acceptance, sold through electrical wholesale distributors, seeks agency representation in the following trading areas: Albuquerque, Oklahoma City, Tulsa, Amarillo, Dallas, Fort Worth, Jacksonville, Tampa, Miami, Birmingham, Montgomery, Mobile. Please forward resume, including educational background, lines now handled and territory covered, to Box 428, Publications Office, Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

WANTED—LIGHTING SPECIALISTS

State Manufacturers' Representative requires one man for West Coast, and one for Northern Florida. Should be experienced writing specs with Architects and Engineers, capable of negotiating large contracts with Wholesalers and Contractors for outstanding national lines, highest quality Fluorescent, Incandescent, Stage Lighting and Dimmer Systems. Now specified and installed locally and internationally. Men must live in area. Consider qualified man willing to relocate. Bert Berend, 1125 Marseille Dr., Miami Beach, Fla.

REPRESENTATIVES WANTED

Recessed incandescent New York City manufacturer has several territories still open for qualified lighting sales engineers. New, quality equipment with advanced design features for architect and engineer specification. Modern facilities now in production. Completely equipped testing laboratory. Outstanding new technical lighting catalog. Write territory covered and lines handled to:

PRESIDENT
OMEGA LIGHTING, INC.
545 Fifth Avenue
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BOOKS AND PAMPHLETS

Eye, Film, and Camera in Color Photography, by Ralph M. Evans, published by John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y., 1959, 410 pages, illustrated and indexed. $8.95.

This book is based on the many lectures given by the author on the difference between what an observer sees when he looks at a scene and what he sees when he looks at an "accurate" color photograph of the same scene. The differences and how the photographer can offset them or use them are shown. Chapter titles include "The Nature of Color Photography," "How We See Things," "How the Camera Sees Things," "Color and Form in Photography," and "The Perception of Light and Color in Photographs." A 19-page bibliography on psychology of vision, photography, color, optics and art is also included.

Mr. Evans is the Director, Color Technology Division, Eastman Kodak Co., Rochester, N. Y. He has been active in color photography for over 30 years.

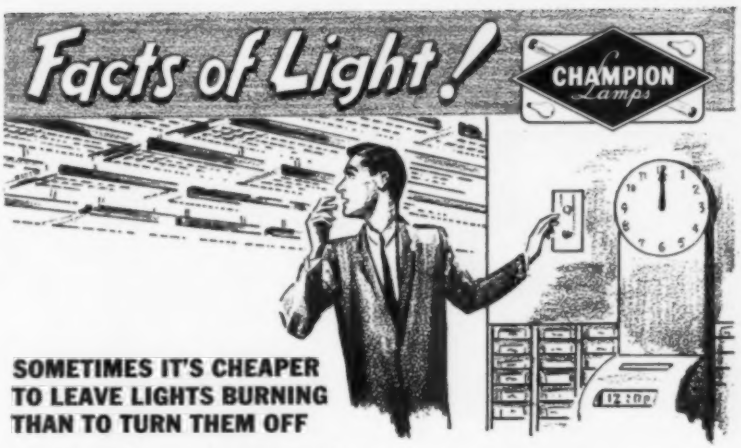
Primer of Lamps and Lighting, by Willard Allphin, published by Chilton Co., Book Division, 56th and Chestnut Sts., Philadelphia 39, Pa., 1959, 241 pages, illustrated, indexed, with separate calculator. $10.00.

This book deals with such subjects as light and lighting terms, incandescent lamps, fluorescent lamps, mercury lamps, light meters, calculations, lighting layouts and home lighting. To simplify calculations, a "Lighting Calculator Slide Rule," and a chapter explaining its use, are included.

The author, who is with Sylvania Electric Products, has intended that this book be useful particularly to salesmen and countermen of lamp and equipment distributors, electrical contractors, building maintenance superintendents, electrical foremen, students in vocational and technical high schools and practicing architects, as well as engineers.

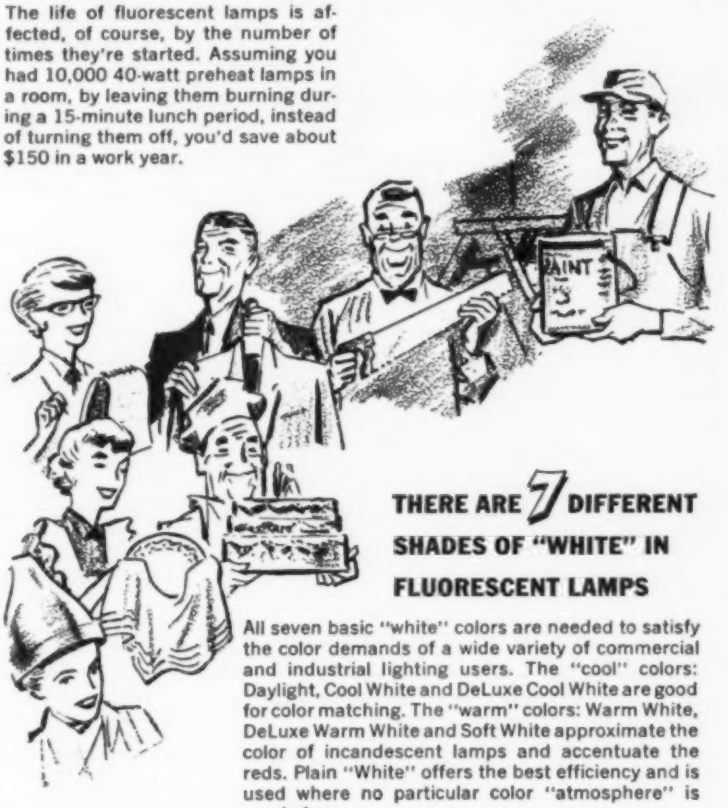
Modern Science Dictionary, compiled by A. Hechtlinger, published by Franklin Publishing Co., Inc., Palisade, N. J., 1959, 784 pages, illustrated. $10.00.

This dictionary is intended to cover every branch of science taught in today's high schools, and to be useful to both the student and the average adult. There are 15,000 definitions—from a. to zymogen. Subjects covered are astronomy, biology, chemistry, geology, meteorology, and physics, including illumination.



SOMETIMES IT'S CHEAPER TO LEAVE LIGHTS BURNING THAN TO TURN THEM OFF

The life of fluorescent lamps is affected, of course, by the number of times they're started. Assuming you had 10,000 40-watt preheat lamps in a room, by leaving them burning during a 15-minute lunch period, instead of turning them off, you'd save about $150 in a work year.



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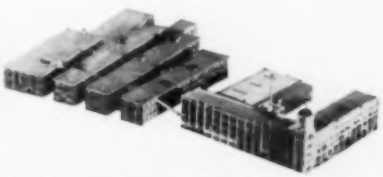

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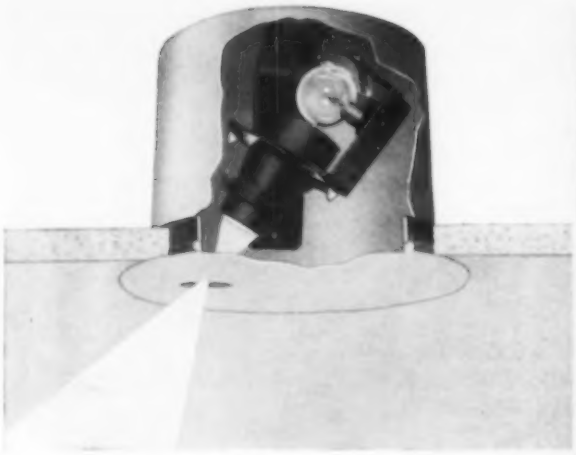

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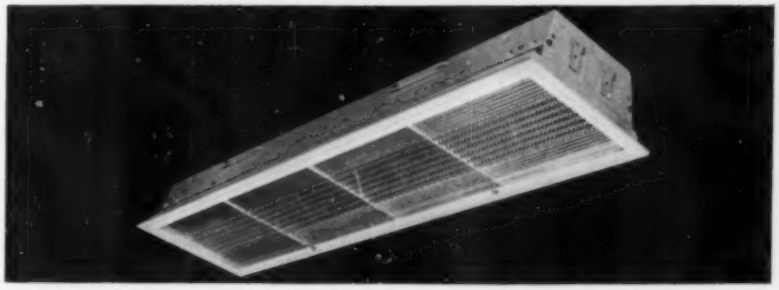

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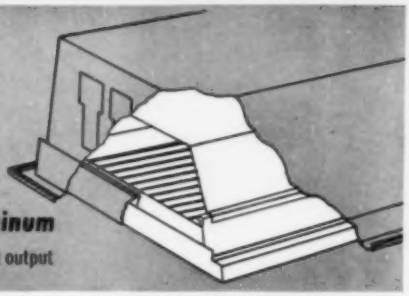

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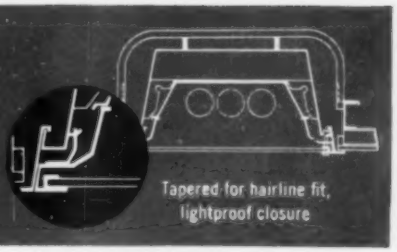

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Now you can insure that your indoor mercury lighting installation will start and keep going even when temperatures slip far below zero. No longer is it necessary to use special, premium-priced indoor transformers or the still more costly weatherproof outdoor type for low temperature indoor installations. Sola's new standard line of indoor constant-wattage mercury lamp transformers keeps H-1, H-25, and H-33 lamps working down to minus 20°F. Two-lamp and single lamp units are both available for these input voltages: 115, 208, 230, 277, 460, and 575. They are ideal for shed, dock and warehouse installations as well as indoor remote mounting to serve outdoor mercury circuits.

These indoor transformers have new, lighter-weight core and coil construction for easier handling. Long leads and twelve knockouts in the new-designed case permit quick and easy connection. The case is liberally perforated for plenty of air circulation around the core and capacitors to give cool, trouble-free operation.

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